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NOTES AND FORMULÆ

FOR

MINING STUDENTS

J. H. MERIVALE, M.A

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Mining

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NOTES AND FORMULÆ

FOR

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NOTES AND FORMULÆ

FOR

MINING STUDENTS.

BY

JOHN HERMAN MERIVALE, M.A.

CERTIFICATED COLLIERY MANAGER; MEMBER OF COUNCIL OF THE N. OF ENGLAND INST. OF MINING AND MECHANICAL ENGINEERS; AND PROFESSOR OF MINING IN THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-UPON-TYNE.

Second Edition, Revised.

LONDON:

CROSBY LOCKWOOD AND SON,

7, STATIONERS' HALL COURT, LUDGATE HILL.

1888.

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C. F.

PREFACE.

THE following pages do not profess to contain much original matter. They are a collection of notes and formulæ, drawn from various sources, my authority being quoted in most instances, and were originally compiled for the students in the Durham College of Science, because I could find no suitable text-book at a moderate cost. They are now re-issued, revised, and enlarged, in a form which I trust may be useful not only to students but to my professional brethren.

The principal sources of information upon mining matters are the Transactions of the various engineering societies to which the student, in most of our large towns, has access. I have given a great many references to the most familiar of them, so that the student, who wishes to follow up a subject, may be in a position to acquaint himself with details which want of space does not permit me to include in a work like this.

The examples of the use of the formulæ, which I have added at the end of the book, are merely given to assist students working without a teacher, and are

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not intended to furnish practical designs for mining appliances.

I should like to take this opportunity of thanking my colleagues for the valuable assistance they have given me in the revision of my Notes.

J. H. M.

NOTE TO THE SECOND EDITION.

I HAVE taken the opportunity of the demand for a New Edition to correct a few verbal inaccuracies, and to substitute for the paragraphs relating to the Mines Act of 1872 others relating to the present Act.

J. H. M.

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SYSTEM OF WORKING.

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GENERAL PROPERTIES OF AIR AND GASES.

CHEMISTRY.

THE GASES.

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EXAMPLES OF THE USE OF FORMULÆ.

ABBREVIATIONS USED THROUGHOUT THE BOOK.

Trans. N.E.I. = Transactions of the N. of England Inst. of Mining and Mechanical Engineers.

Proc. I.M.E. = Proceedings of the Inst. of Mechanical Engineers.

Proc. I.C.E. = Proceedings of the Inst. of Civil Engineers.

RANKINE M.M. = RANKINE's Machinery and Mill Work.

RANKINE S.E. = RANKINE's Steam Engine.

E.M.F. = Electro-motive force.

HP = Horse-power.

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NOTES, FORMULÆ, &c.,

FOR

MINING STUDENTS.

INTRODUCTION.

COURSE OF STUDY FOR MINING STUDENTS.

I AM frequently asked by students to advise them as to the course of study they should pursue in order to pass the Colliery Managers' examination; or, more generally, to enable them to become properly qualified mining engineers.

So far as the certificate is concerned, I have always found (premising, of course, a thorough knowledge of reading, writing, and arithmetic), that an intimate acquaintance with all the details of a colliery, both above and below ground, is of much more importance than book learning. The student should, however, have the Mines Act, General and Special Rules at his fingers' ends, and such a knowledge of the theory of the gases and ventilation as may be obtained from Atkinson's book. But, of the man who aspires to a high place amongst the mining engineers of the next generation, something more than this is required. Every year the necessity of a thorough grounding in certain departments of science is becoming more apparent, and I have no hesitation in saying that the successful English mining engineer of the future will have to be (as his continental rival long has been), not only a good practical man, but a man of science as well.

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I would advise, then, a good general education up to the age of about sixteen, such as would enable him to pass the examination in general knowledge now required by most of the professions. He should then go through the following course of study which can be pursued in one or other of the science colleges :—

Mathematics.

Euclid.—Books I., II., III., IV., VI., XI., and the definitions of Book V.

Arithmetic.

Algebra as far as the Binomial Theorem.

Trigonometry, including the solution of triangles and the use of logarithms.

The laws and principles of *Mechanics*, and the properties of *Conic Sections* treated Geometrically.

Analytical Geometry of two dimensions.

The elements of the *Differential and Integral Calculus*, with one independent variable.

Statics and Dynamics treating of forces in one plane.

The elementary parts of *Hydrostatics* treated mathematically.

Experimental Physics.

Elementary Mechanics, Heat, Sound, Light, and Electricity.

Advanced mechanics, Heat, Magnetism, and Electricity; special attention being paid to the strength of materials, the construction and use of Hydraulic and Pneumatic Machines, the Measurement of Gases, the Conservation of Energy, the Theory of the Steam Engine, Electric Lighting, Electric Signalling, and the Transmission of Power.

Laboratory Practice.

Chemistry.

General Principles of Chemistry; History of the Non-Metallic Elements.

History of the Metals and their more important native and artificial compounds; Principles of Qualitative Analysis.

Laboratory Practice.

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Geology.

Elementary Mineralogy and Lithology (with demonstrations).

Physical Geology.

Stratigraphical Geology and Elementary Palæontology, with Special Reference to the British Isles.

Mining Geology, or Descriptive Geology, with special reference to the Coal-producing and Metalliferous regions of the world.

Geological Surveying.—As far as possible the instruction should be given in the field, and should be of such a nature as to give students a practical knowledge of Elementary Geological Surveying and "prospecting."

Mechanical Drawing.

Plane Geometry.—Construction and use of scales; construction of various polygons; delineation of the various curves; miscellaneous problems relating to lines, circles and plane figures.

Solid Geometry.—Miscellaneous problems of lines and planes represented by plan and elevation, &c. Determination from various data of the projection of solids. Intersections, Isometrical projection.

Constructional Drawing.—Detailed drawings of various examples of building construction.

Mechanical Drawing.—Detailed drawings of working parts. Drawings of Miscellaneous Machines and Engineering Structures. Working and finished drawings. Drawings from models and actual machines.

Modern Languages.

Although a colloquial knowledge of modern languages may not be necessary, the student should at least be able to read French and German mining literature.

Such a course as this would take from two to three years, according to the previous education of the student. It should be begun at about the age of sixteen, prior to the four or five years' practical training.

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THE CERTIFICATED MANAGERS' EXAMINATION.

Speaking generally, the candidate must be 22 years of age or upwards, and have had five years' experience at a colliery. The subjects for Examination are Reading, Writing, Arithmetic, the Geology of the district in which the Examination is held, the Mines' and Explosives' Acts and Mine Engineering; but, as each district has its own rules, rules too which are changed from time to time, the candidate should apply to the Secretary.

MINING DISTRICT.	CHIEF INSPECTOR. Address and Date of Appointment.	ASSISTANT INSPECTOR. Address and Date of Appointment.	SECRETARY TO BOARD OF EXAMINATIONS. Address and Date on which Examinations usually held.
Manchester and Ireland.	Joseph Dickinson, South Bank, Pendleton, Manchester. 1850.	J. Turton, jun., 75, Manchester Road, Bolton. 1885.	Maskell W. Peace, King Street, Wigan. December.
North Staffordshire.	Thomas Wynne, Gnosall, Stafford. 1852.	A. R. Sawyer, Basford, Stoke-on-Trent. 1879.	Joseph Knight, Newcastle-under-Lyne. June.
Scotland (Western Division).	J. M. Ronaldson, Pollokshields, Glasgow. 1875. In charge 1886.	G. F. Bell, Hill Head, Glasgow. 1886.	Stuart Foulis, 135, St. Vincent Street, Glasgow. November.
Midland.	A. H. Stokes, Greenhill, Derby. 1874. In charge 1887.	W. H. Hepplewhite, Leicester. 1885.	Wm. Saunders, The Wardwick, Derby. October.
Scotland (Eastern Division).	Ralph Moore, 13, Clairmont Gardens, Glasgow. 1862.	R. McLaren, Coatbridge. 1885.	Robert Calder, 296, Renfrew Street, Glasgow. May.

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South Wales.	J. T. Robson, 1873. In charge 1887.	E. W. Randall, Penarth, Cardiff. 1883. F. A. Gray, Swansea. 1886.	C. H. James, 8, Courtland Terrace, Merthyr Tydfil. January.
Yorkshire.	Frank N. Wardell, Wath-upon-Dearne, Rotherham. 1867.	John Gerard, Wakefield. 1874. James Mellors, Leeds. 1885.	John R. Jeffery, 5, Piccadilly, Bradford. June.
Newcastle-upon-Tyne.	James Willis, Newcastle-upon-Tyne. 1871.	J. B. Atkinson, Stocksfield, Newcastle-upon-Tyne. 1873. R. P. W. Oswald, Brigham, Carlisle. 1885.	Fred. Gosman, The Mining Institute, Newcastle-upon-Tyne. January.
Durham.	Thomas Bell, Durham. 1873.	W. N. Atkinson, Shincliffe Hall, Durham. 1873. J. Plummer, Bishop Auckland. 1885.	G. W. Bartlett, Tees Grange, Darlington. July.
Liverpool.	Henry Hall, Rainhill, Prescot. 1873. In charge 1875.	J. L. Hedley, Chester. 1874.	Maskell W. Peace, King Street, Wigan. June.
South Western.	J. S. Martin, Swansea. 1873. In charge 1886.	R. Donald Bain, Newport, Monmouthshire. 1877.	J. T. Thomas, Coleford, Gloucester. July.
South Staffordshire.	W. B. Scott, Parkdale, Wolverhampton. 1873. In charge 1883.	W. H. Pickering, Finchfield, Wolverhampton. 1883.	W. Blakemore, Shelfield, Walsall. January.

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THE COAL FIELDS OF GREAT BRITAIN AND IRELAND.

THE rocks forming the earth's crust are divided by geologists into two groups, viz.:—

The Aqueous or Stratified;
The Igneous or Unstratified.

These groups are subdivided into numerous systems, and in one of the systems of the stratified group coal is found in such large quantities as to have conferred upon it the title of the Carboniferous System.*

The table following shows the systems of the stratified group and their subdivisions in descending order, beginning with the superficial deposits down to the lowest known depths.

At the commencement of the Lower Carboniferous period (upper old red sandstone) the greater part of the British Isles, south of Perth, appears to have been occupied by two seas, separated the one from the other by a ridge of land passing through the centre of Wales, Shropshire, Worcester-

---

* It must not, however, be supposed that coal is found only in the Carboniferous system. As a matter of fact, it occurs more or less in every one of the Aqueous divisions. For example:—

In the Tertiary we have the lignites worked for many years at Bovey Tracey, in Devonshire; and the lignites, brown coals, and pitch coals of the continent.

The Cretaceous contains lignite and bituminous coal in Spain, Germany, New Zealand, and South America.

The Jurassic: The Kim-coal of Kimmeridge, the moorland coal of Yorkshire, and the coal of Brora in Sutherlandshire. Besides these, there are many lignites and bituminous coals worked on the continent.

The coal-fields of India, and a part of the Australian coal-fields, are in the Triasso-Jurassic formation.

The Permo-Carboniferous furnishes coal in North America, Bohemia, and Autun in France. In the Devonian are situated some of the coal-fields of N. W. France, as in Mayenne. From the Silurian, coal has been worked in Portugal.

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TABLE I.

TABLE OF THE CHIEF DIVISIONS RECOGNIZED IN THE SEDIMENTARY ROCKS OF BRITAIN.

Those Formations which occur in Northumberland and Durham are denoted by asterisks.

TABLE OF STRATIFIED ROCKS.

[N.B.—The figures give *maximum* thicknesses only.]

	PERIODS.	SYSTEMS.	FORMATIONS.	LIFE-PERIODS.
	QUATERNARY.	POST-TERTIARY or PLEISTOCENE (250 ft.)	*Peat, Cave and Valley-Gravel Deposits. *Brick-earths and Loess. *Raised Beaches, &c. *Boulder-Clay and Gravels.	Dominant type, Man.
Represented locally by a break in the succession.	TERTIARY or CAINOZOIC.	PLIOCENE (100 ft.)	Norwich, Red, and Coralline Crags.	Dominant types, Birds and Mammals.
		MIOCENE (125 ft.)	Bovey Beds (?).	
		EOCENE (2,600 ft.)	Fluvio-Marine Series. Bagshot Beds. London Tertiaries.	
	SECONDARY or MESOZOIC.	CRETACEOUS (7,000 ft.)	Maestricht Beds. Chalk. Upper Greensand. Gault. Neocomian. Wealden.	
		JURASSIC (3,000 ft.)	Purbeck Beds. Portland Beds. Kimmeridge Clay. Coral Rag. Oxford Clay. Great Oolite. Inferior Oolite. Lias.	Dominant type, Reptilia.
		TRIASSIC (3,000 ft.)	Rhætic. Keuper. Muschelkalk. *Bunter (?).	
Break (unconformity).		PERMIAN (500 to 3,000 ft.)	*Red Sandstone and Marl. *Magnesian Limestone, &c. *Yellow Sand.	Dominant type, Fishes.
	PRIMARY or PALÆOZOIC.	CARBONIFEROUS (20,000 ft.)	*Coal Measures and Millstone Grit. *Carboniferous Limestone or Bernician Series. *Tuedian and Basement Beds or Up. Old Red Sandstone.	
Break represented by the Cheviot Rocks.		DEVONIAN (5,000 to 10,000 ft.)	Devonian. Old Red Sandstone.	Dominant type, INVERTEBRATA.
		*SILURIAN (3,000 to 20,000 ft.)	Upper Silurian. LowerSilurian orOrdovician	
		CAMBRIAN (20,000 to 30,000 ft.)	Cambrian.	
		PRE-CAMBRIAN, &c. (30,000 ft.)	Pre-Cambrian.	

Range of Invertebrata and Plants in time.
Range of Fossil Fishes in time.
Footprints of Birds?.......Range of Fossil Reptilia in time.
Range of Fossil Birds in time.
Range of Fossil Mammals in time.

[G. A. LEBOUR.]

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shire, and south Staffordshire, into the Eastern Counties. These seas were gradually filled up with limy ooze, sand, and mud; so that, at the commencement of the Upper Carboniferous period (coal measures), they had become two large swamps. In these swamps the vegetation grew which now forms our seams of coal. Each seam marking a period when the swamps were above water, the intervening beds of sandstone and shale a period when they were below.

At the close of the Carboniferous period the earth's crust in these districts was upheaved along several parallel east and west lines. Taking the North of England as an example, two of these axes of upheaval passed, the one to the north, the other to the south, of the present Newcastle coalfield. The denuding agencies of rain, frost, &c., planed off the tops of the ridges, sweeping away the rocks lying high up in the series, together with the seams of coal; the result being that the Newcastle coalfield occupied the eastern portion of a trough of coal measures extending from the west of Ireland to the German Ocean; and this trough was separated from similar troughs to the north and south (now occupied in part by the coalfields of the south of Scotland and Yorkshire, &c.) by tracts of country denuded of their coal. Upon these troughs of coal measures and barren intervening country the Permian, the next formation in ascending order, was deposited. Again, there was a period of upheaval; but now along lines running north and south. One of these ran to the west of Newcastle, and formed the Pennine chain, or great central ridge of the North of England. Again, the agents of denudation set to work, planed down the arch and separated the Newcastle coalfield from that of Whitehaven.

It is to the intersection of these two series of axes of upheaval, approximately at right angles the one to the other, that the basin shape of our coalfields is due; while the dis-severance of these basins the one from the other has been the necessary consequence of the planing down and sweeping away of the arches by the action of rain, ice, &c.

The fields of coal now left to us by denudation are shown in the following table. The names of the districts are not those of the separate basins, but the groups into which they have been divided under the Coal Mines Act.

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TABLE II.

Mines included under the Coal Mines' Act.

Names of Districts.	Persons Employed.	Coal.	Fire Clay.	Ironstone.	Shale, &c.	Total.	Mines.	Lives Lost.
Northumberland, Cumberland, and North Durham	53,011	16,427,529	320,939	773	5,086	16,754,327	203	91
South Durham, Westmoreland and North Yorkshire	55,771	20,402,479	221,013	—	—	20,623,492	194	78
Cleveland (Ironstone)	6,713	—	—	5,932,244	—	5,932,244	36	10
North and East Lancashire	31,640	9,738,674	96,696	—	90	9,835,460	287	229
Ireland	860	109,035	900	—	—	109,935	27	1
West Lancashire and North Wales	41,565	13,176,944	59,047	2,594	2,098	13,240,683	225	97
Yorkshire	63,562	18,497,778	200,722	126,596	57,753	18,882,849	395	84
Lincolnshire (Ironstone)	115	—	—	81,521	—	81,521	10	1
Derby, Leicester, Nottingham, and Warwick shires	55,163	16,963,684	77,122	29,386	4,051	17,074,243	355	73
North Stafford, Cheshire, and Shropshire	21,889	6,324,600	66,000	1,920,920	15,392	8,326,911	225	46
South Stafford and Worcestershire	23,137	9,862,497	185,632	117,726	2,457	10,168,312	365	29
Monmouth, Somerset, parts of Glamorgan and Breconshire	35,659	9,352,072	88,277	26,037	11,632	9,478,018	294	70
South Wales	61,617	17,207,540	106,920	35,656	6,704	17,356,820	305	224
Scotland, East	46,022	14,905,620	192,826	504,023	1,665,667	17,268,136	323	75
Scotland, West	23,908	6,382,966	262,420	1,331,136	114,487	8,091,009	244	42
Totals in 1885	520,632	159,351,418	1,878,514	10,108,612	1,885,416	173,223,960	3,488	1,150
Do. in 1884	520,376	160,757,779	2,053,927	10,412,443	1,648,610	174,872,759	3,554	942
Do. in 1883	514,933	163,737,327	2,189,452	11,495,401	1,341,210	178,763,390	3,707	1,054

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THE NEWCASTLE COALFIELD (NORTHUMBERLAND AND DURHAM).

Section of the Strata.

The Post Tertiary, all four divisions of which are found; but more especially the *Boulder clay*, which consists, for the most part, of stiff blue and brown clays, with boulders of limestone, sandstone, basalt and porphyrite. It covers almost the whole of the coalfield.

The Permian Formation, about 600 feet thick. It extends over the East and South-East of Durham. It rests unconformably upon the coal-measures, and consists of the magnesian limestone, and the yellow sand (often very wet and loose), and produces limestones; but no coal.

The Coal Formation probably extends (either at the surface or beneath more recent formations) over the whole of Durham or Northumberland, excepting the Cheviot district. It may be subdivided into—1. The Upper Coal Measures, from the base of the Permian to the roof of the High Main Seam, about 1,100 feet. Here are found the Hebburn Fell, Five Quarter, and Three Quarter Seams. 2. The Middle Coal Measures, from the roof of the High Main to the floor of the Brockwell, about 900 feet. Here are found all the best * seams of the district, some sixteen in number, of a thickness, in the aggregate, of about 50 feet, discarding those less than 18 inches. Fifty feet, however, will not be found in any one section; but 30 feet may be taken as an average. 3. The Lower Coal Measures and millstone grit formation, from the floor of the Brockwell to the roof of the Fell-top limestone, perhaps 600 feet, contain no seams of any present

* Amongst these the following may be mentioned:—The High Main of Northumberland (a house coal) is the Three Quarter of the Hetton district (an inferior coal) and the Shield-row of Pontop (a gas coal).

The Metal coal and the Stone coal of the Tyne run together to form the Grey Seam of Northumberland (a steam coal) and the Five

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value. 4. The Bernician, from the roof of the Fell-top limestone to the base of the Harbottle grits, 2,500 to 8,000 feet. Several seams of coal are found here; but they are variable in quality, thickness, and extent. The best known are, perhaps the little limestone coal, and the Shillbottle seam. 5. The Tuedian beds from the base of the Harbottle grits to the Silurian formation.

By the term, "The Newcastle Coal Field," only the upper and middle coal measures are usually meant. These extend approximately from the Coquet to the Tees, and may be divided into—

Exposed coal field . .	460	square miles.
Beneath the Permian . .	225	"
Beneath the sea . . .	111	"
	796	square miles.

It was estimated, in 1870, that the upper and middle coal measures contained . .	7,452,250,000	tons.
The limestone coal . . .	580,000,000	"
	8,032,250,000	"

Quarter of the Hetton and Pontop districts (a house coal). The Metal coal produces house coal.

The yard seam of Northumberland (steam) is the Main coal of Hetton (house) and the Brass Thill of Pontop (a gas coal).

The Bensham of Northumberland (steam) is the Maudlin of Hetton (gas and house).

The Five Quarter of Northumberland (steam) is the Low Main of Hetton (steam and house).

The Bensham and Five Quarter run together to form the Hutton Seam of Pontop.

The Low Main of Northumberland (steam) is the Hutton Seam of Hetton (house) and the Main coal of Pontop (coke).

The Beaumont of Northumberland (unworked to the east) is the Harvey of Hetton (gas and coking) and the Towneley of Blaydon (house coal).

The Stone coal and Five Quarter, found in the S.W. of Northumberland (steam and house coal) unite to form the Busty Bank of Pontop (coking and gas coal).

The Brockwell, not worked in E. Northumberland, is a house coal at Blaydon and a coking coal about Brancepeth.

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including all seams above 18 inches thick, and not more than 4,000 feet deep. Since that date about 400,000,000 tons have been worked.

Dykes.

The principal whin dykes run east and west, and "are remarkably uniform in lithological composition. They are, as a rule, close-grained basalts, deep blue when freshly broken, and weathering to brown or red." The following may be mentioned beginning from the North:—*Acklington*, *Bedlington*; *Hartley*; and *Coley-Hill*, in Northumberland; *Hebburn*, the southern extension of Coley-Hill; *Hett*; and *Cockfield* in Durham.

Troubles.

These, too, run for the most part east and west. The most important, beginning from the north, are:—Dipper South, of about 50 fathoms, between Newbiggin and North Seaton; the *Ninety-fathom Dyke*, a dipper North, which runs from Cullercoats, between Killingworth and Gosforth Collieries south of Newburn, through Whittonstall to a little west of Minsteracres, where it dies out; *Stublick*, a dipper North, which, starting from a little to the south of Corbridge, runs west into Cumberland; and *Butterknowle*, from Wingate Grange to Butterknowle, a dipper South of 40 fathoms.

Mineral Products, 1881.

Coal, 35,592,420 tons from 365 collieries. Iron ore, 70,771 tons from Weardale. Fireclay, 438,251 tons, Durham principally. Lead ore, 17,467 tons; Silver, 54,036 oz.; Pyrites, 5,466 tons; Barytes, 5,435 tons: from the Bernician. Limestone for furnace linings from Permian; for a flux and agricultural purposes from Permian and Bernician. Basalt for road metal from dykes. Sandstone for building, grindstones, and filters. Cement stones from the Tuedian. Since 1881 Salt has been pumped near Middlesborough; but there has been a decrease in the production of iron ore, and lead.

The important commercial position of this district is due

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—1st. To the numerous seams of coal, which are thick, produce the best coal of every kind, and are cheaply worked. 2nd. To the position of the coal along a coast line, indented with many natural harbours. 3rd. To the near neighbourhood of the Cleveland ironstone (Lias). 4th. To sundry minor advantages, such as the lead, fire-clay, and building stones; and now the salt (Trias, or upper Permian) found in the neighbourhood of Middlesborough, at a depth of about 200 fathoms.

The Drawings and persons employed in Northumberland and Durham during the seven years, 1879—85, have been:—

TABLE III.

		Tons.	Persons Employed.
1879.	Northumberland	5,537,071	22,153
	North Durham	6,105,259	17,900
	South Durham	17,146,644	49,556
1880.	Northumberland	6,850,162	23,048
	North Durham	7,075,846	18,528
	South Durham	20,987,500	53,224
1881.	Northumberland	7,074,577	22,740
	North Durham	6,986,930	18,481
	South Durham	21,530,913	54,810
1882.	Northumberland	7,060,783	23,368
	North Durham	7,458,006	19,529
	South Durham	21,780,808	55,969
1883.	Northumberland	7,527,065	23,793
	North Durham	7,738,870	19,621
	South Durham	22,139,565	57,067
1884.	Northumberland	7,516,005	25,423
	North Durham	7,618,254	20,403
	South Durham	20,934,049	56,533
1885.	Northumberland	7,354,776	26,519
	North Durham	7,340,007	19,712
	South Durham	20,397,317	55,729

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TABLE IV.

The Principal Coal Fields of the World.

	Estimated area in square miles.	Estimated thickness in feet.	Produce in 1880, in millions of tons.	Consumption in 1880, in millions of tons.	Produce per man employed in 1880, in tons.
United States	196,000	20	70·3	70·1	
Australia	30,000		1·8		
China	20,000				
British North America (1884)	7,500	20	1·87		
Great Britain	5,500	35	149·3	130·1	337
British India (1883)...	2,500	50	1·31		
Russia	2,000		2·9		
Prussia	1,500		59·2	56·8	295
France	1,000	60	19·4	28·5	166
Belgium	550	60	16·9	12·1	164
Austro-Hungary			16·0	14·6	
New Zealand (1884)			0·48		
New S. Wales (1884)			2·75		

Composition of Coal.

Coal varies in composition as it passes from lignite, the first stage in its production from vegetable matter, through its subsequent stages into anthracite. This is shown in the following table, after Thomas, "Coal, Mine-gases, and Ventilation," p. 6.

TABLE V.

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.
Wood	50·0	6·0	41·5	1·0		1·5
Lignite	56·0	5·0	25·0	1·5	2·0	10·5
House Coal ...	81·0	5·0	8·0	1·5	1·0	3·5
Steam Coal ...	89·0	4·0	2·5	1·0	1·0	2·5
Anthracite ...	91·5	3·0	1·5	1·0	1·0	2·0
Cannel	80·0	6·0	7·0	1·5	1·0	4·5

Produce of Coal Seams, &c.

The produce depends upon the specific gravity of the coal (1·25 to 1·50), the system of working, and the number of faults, balks, etc. A rough and ready rule is to calculate

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the produce at 100 tons per inch per acre, which leaves an ample allowance (about 25 per cent.) for loss of every kind. The weight in the seam per inch per acre = specific gravity × 101.

At a colliery in Durham, working the Harvey Seam, 3 feet 6 inches thick, 5,185 tons per acre were got when working long wall; 5,052 tons bord and pillar.

TABLE VI.

WEIGHT PER SQUARE FATHOM ONE INCH THICK OF VARIOUS ORES IN POUNDS.

Gold Native	3,281·25	Zinc Red Oxide	1,012·50
Silver do.	1,875·00	Blende Zinc Sulphide	750·00
Copper do.	1,668·75	Nickel Glance	1,406·25
Vitreous Copper	1,050·00	Cobalt Glance	937·50
Copper Pyrites	787·50	Iron Pyrites	912·75
Red Copper	1,106·25	Magnetite	1,016·25
Malachite (Carbonate of Copper)	712·50	Arsenical Iron Ore	1,068·75
Tin Oxide (Cassiterite)	1,256·25	Specular do.	912·75
Galena (Lead Sulphide)	1,406·25	Hæmatite	750·00
Lead Carbonate (Cerussite)	1,200·00	Pitch Blende (Uranium)	1,312·50
		Baryta	750·00

The Coal Commission of 1871, estimated that 146,480,000,000 tons of available coal were left in Great Britain and Ireland; including no seams less than one foot thick, or at a greater depth than 4,000 feet. Since then, about 2,000,000,000 tons have been worked.

Authorities :—"Extent and Duration of the Northern Coal Field;" T. Y. Hall, Trans. N.E.I., ii. 104. "Rivers, Ports and Harbours of the Northern Coal Field;" T. Y. Hall, Trans. N.E.I., x. 41. "Outlines of the Geology of Northumberland and Durham," Lebour; "The Coal Fields of Great Britain," Hull. "Coal: Its History and Uses," Green, Miall, etc. Several Papers in the "Trans. N.E.I. Mining Records," Hunt. "The Coal Seams of the Northumberland and Durham Coal Field," J. B. Simpson. The Report of the Coal Commission, 1871. The Reports of the Inspectors of Mines.

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THE STRENGTH OF MATERIALS;

Some approximate formulæ.

	Strain.	Fracture.	
Elementary.	Extension.	Tearing.	(Ropes.)
	Compression.	Crushing.	(Short Columns.)
Compound.	Distortion.	Shearing.	(Rivets.)
	Twisting.	Wrenching.	(Shafts.)
	Bending.	Breaking across.	(Beams.)

The *factor of safety* is the ratio that the breaking strain should bear to the working load; it depends upon the nature of the load and the material, as follows (with some exceptions) :—

Material.	Dead Load.	Live Load.
Metal........................	3	6
Masonry and Brickwork	4	8
Wood and Hemp.........	5	10

The *proof strain* should be from $\frac{1}{3}$ to $\frac{1}{2}$ the breaking strain; or twice the working load.

Round Ropes.

W = Breaking load in tons.
C = Circumference of rope in inches.

(1.) $W = 0{\cdot}25C^2 \therefore C = \sqrt{\frac{W}{{\cdot}25}}$ for hemp ropes.

(2.) $W = 1{\cdot}50C^2 \therefore C = \sqrt{\frac{W}{1{\cdot}5}}$ for iron wire ropes.

(3.) $W = 3C^2 \therefore C = \sqrt{\frac{W}{3}}$ for crucible steel wire ropes.

(4.) $W = 4C^2 \therefore C = \sqrt{\frac{W}{4}}$ for improved plough steel wire ropes.

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As the sizes of ropes are usually referred to their circumferences, the following formulæ will be useful :—

c = Circumference in inches.
A = Area in square inches.
d = Diameter in inches.

(5.) $c = 3{\cdot}1416d = \sqrt{12{\cdot}5664A}.$

(6.) $A = {\cdot}7854\ d^2 = \dfrac{c\,d}{4} = {\cdot}07958c^2.$

(7.) $d = \dfrac{c}{3{\cdot}1416} = {\cdot}3183c = \sqrt{\dfrac{A}{{\cdot}7854}}.$

In calculating the size of rope required to support a given weight, the weight of the rope itself must be taken into account; but the weight of the rope cannot be calculated until its size is known.

If c = circumference of rope in inches.
w = weight roughly in lbs. per fathom.

(8.) $w = \dfrac{c^2}{4}$ hemp.

(9.) $w = \dfrac{c^2}{1{\cdot}2}$ iron or steel.

Combining these formulæ with formulæ (1), (2), (3), and (4), we get—

(10.) $c = \sqrt{\dfrac{L}{\dfrac{0{\cdot}25}{M} - \dfrac{F}{4 \times 2240}}}$ for hemp.

(11.) $c = \sqrt{\dfrac{L}{\dfrac{1{\cdot}5}{M} - \dfrac{F}{1{\cdot}2 \times 2240}}}$ for iron.

(12.) $c = \sqrt{\dfrac{L}{\dfrac{3}{M} - \dfrac{F}{1{\cdot}2 \times 2240}}}$ for crucible steel

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$$(13.)\quad c = \sqrt{\frac{L}{\frac{4}{M} - \frac{F}{1{\cdot}2 \times 2240}}} \text{ for improved plough steel.}$$

Where c = circumference of rope in inches.
L = Load, viz., full cage and chains in tons.
M = Factor of safety (from 6 to 10).
F = Depth of pit in fathoms.

At a certain depth, the weight of the rope will be equal to the safe working load. Thus for round crucible steel ropes with say 8 as factor of safety, we see from formulæ (3) and (12), that the limit of depth in fathoms is:—

$$\frac{2240\frac{3c^2}{8}}{\frac{c^2}{1{\cdot}2}} = 1{,}008 \text{ fathoms.}$$

When the time arrives to work mines at such depths, taper ropes must be used, see formulæ (14) and (15), or the mineral raised in more than one lift.

Round Taper Ropes.

Are made of a decreasing size from the top to the bottom, so that they may be as strong at the top, where the strain is greatest, as they are at the bottom, where the strain is least.

A = Area of rope at any point in square inches.

a = Area of rope at bottom end in square inches.

w = Weight of one cubic inch of the rope in lbs. (For an iron or steel rope w = 0·14, for a hemp rope w = ·043. Both these numbers are approximate only, as the weight depends partly upon the size of the rope.)

L = Safe load in lbs. per square inch of section of rope (say, Iron, 7,000; Steel, 11,500; Plough Steel, 13,440; Hemp, 740).

D = Distance in inches from A to a.

W = Weight of rope in lbs.

e = 2·7182.

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$$(14.)\ A = ae^{\frac{wD}{L}}$$

$$(15.)\ W = La\left(e^{\frac{wD}{L}} - 1\right) = L\,(A - a).$$

To avoid the use of logarithms, the following table of the values of $e^{\frac{wD}{L}}$ for distances from 10 to 600 fathoms is given. By it the dimensions of a round plough steel taper rope at points 10 fathoms apart from the bottom to the top can be calculated.

TABLE VII.

Distance from A to a in fms., *i.e.*, $\frac{D}{6 \times 12}$	$e^{\frac{wD}{L}}$	Distance from A to a in fms., *i.e.*, $\frac{D}{6 \times 12}$	$e^{\frac{wD}{L}}$	Distance from A to a in fms., *i.e.*, $\frac{D}{6 \times 12}$	$e^{\frac{wD}{L}}$	Distance from A to a in fms., *i.e.*, $\frac{D}{6 \times 12}$	$e^{\frac{wD}{L}}$
10	1·0075	160	1·1275	310	1·2617	460	1·4119
20	1·0151	170	1·1359	320	1·2712	470	1·4226
30	1·0227	180	1·1445	330	1·2808	480	1·4333
40	1·0304	190	1·1531	340	1·2904	490	1·4441
50	1·0382	200	1·1618	350	1·3001	500	1·4549
60	1·0460	210	1·1705	360	1·3099	510	1·4726
70	1·0539	220	1·1793	370	1·3198	520	1·4769
80	1·0618	230	1·1882	380	1·3284	530	1·4880
90	1·0698	240	1·1972	390	1·3397	540	1·4992
100	1·0778	250	1·2062	400	1·3498	550	1·5105
110	1·0859	260	1·2153	410	1·3600	560	1·5219
120	1·0941	270	1·2244	420	1·3702	570	1·5333
130	1·1024	280	1·2336	430	1·3805	580	1·5449
140	1·1106	290	1·2429	440	1·3909	590	1·5565
150	1·1190	300	1·2523	450	1·4014	600	1·5682

Flat Ropes.

Are formed of two or more round ropes stitched together, and their strength may be calculated accordingly, a deduction being made of about 10 per cent.

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Another rule. C. M. Percy, "Mechanical Engineering of Collieries," p. 71, says:—

Round Ropes.

(16.) $C^2 \times 4$ charcoal iron.
(17.) $C^2 \times 6$ crucible steel.
(18.) $C^2 \times 10$ plough steel.

Flat Ropes.

(19.) Width × thickness × 35 charcoal iron.
(20.) Do. × do. × 55 crucible steel.
(21.) Do. × do. × 70 plough steel, gives the safe working load in cwts.; the dimensions are taken in inches.

Chains.

W = Breaking load in tons.
D = Diameter in sixteenths of an inch.

(22.) $W = \frac{D^2}{9} \therefore D = \sqrt{9W}.$

In this district, the factor of safety used for cage chains is probably about 10, not 6.

Cast Iron Pipes.

Th = Thickness of metal in inches.
D = Diameter of pipe in inches.
H = Head of water in feet that will burst pipe.

(23.) $H = \frac{72{,}000 Th}{D} \therefore Th = \frac{DH}{72{,}000}.$

If W = Weight per linear foot of cast iron pipes in lbs.
D = Outside diameter in inches.
d = Inside do. do.

(24.) $W = 2{\cdot}45\ (D^2 - d^2).$

The weight of the two flanges may be taken as equal to one foot of pipe.

Boiler Shells.

Th = Thickness of plate in inches.
D = Diameter of boiler in inches.
P = Bursting pressure of steam in lbs. per square inch.

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(a) *Iron Boilers.*

(25.) $P=\frac{50{,}000Th}{D} \therefore Th=\frac{PD}{50{,}000}$ (single riveted).

(26.) $P=\frac{60{,}000Th}{D}$ and $Th=\frac{PD}{60{,}000}$ (double riveted)

(b) *Steel Boilers.*

(27.) $P=\frac{70{,}000Th}{D} \therefore Th=\frac{PD}{70{,}000}$ (single riveted).

(28.) $P=\frac{90{,}000Th}{D} \therefore Th=\frac{PD}{90{,}000}$ (double riveted).

Though 6 is usually considered sufficient as the factor of safety, 8 agrees better with the practice of this district.

Boiler Tubes (Iron).

Th = Thickness of plate in inches.
D = Diameter of tube in inches.
L = Length of tube in inches.
P = Collapsing pressure in lbs. per square inch.

(29.) $P=\frac{9{,}672{,}000Th^2}{LD} \therefore Th=\sqrt{\frac{PLD}{9{,}672{,}000.}}$

Masonry Pillars.

W = Crushing load in tons.
A = Area of red brick pillar in square inches.

(30.) $W=\cdot38A \therefore A=\frac{W}{\cdot38}$

See also T in Table IX.

Beams.

L = Length of beam or span in inches.
B = Breadth of beam in inches.
D = Depth of beam in inches.
W = Breaking load in tons.
K = Coefficient of rupture. (See Table VIII.)

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(31.) $W = \dfrac{KBD^2}{L}$ when one end is fixed, and the other end loaded.

(32.) $W = \dfrac{2KBD^2}{L}$ when one end is fixed, and the load distributed.

(33.) $W = \dfrac{4KBD^2}{L}$ when both ends are supported, and the load is in the centre.

(34.) $W = \dfrac{6KBD^2}{L}$ when both ends are fixed, and the load is in the centre.

(35.) $W = \dfrac{8KBD^2}{L}$ when both ends are supported, and the load distributed.

(36.) $W = \dfrac{12KBD^2}{L}$ when both ends are fixed, and the load is distributed.

Circular beams with radius R inches; substitute $4{\cdot}7R^3$ for BD^2 in the above formulæ.

TABLE VIII.

Values of K for Different Materials.

Wrought Iron	$K=3{\cdot}40$
Cast Iron	$K=2{\cdot}30$
English Ash	$K=0{\cdot}95$
Beech	$K=0{\cdot}65$
Fir (Spruce)	$K=0{\cdot}60$
English Oak	$K=0{\cdot}75$
African Oak	$K=1{\cdot}10$
Red Pine	$K=0{\cdot}65$
Yellow Pine	$K=0{\cdot}50$
Memel Pine	$K=0{\cdot}60$
Pitch Pine	$K=0{\cdot}75$

For most purposes, the breadth and depth of the beam should be proportioned, so that, in round numbers, the depth be about $1\frac{1}{2}$ times the breadth.

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If then we put $D = 1\cdot5B$, (31) becomes

$$(37.)\quad W = \frac{KB\,(1\cdot5B)^2}{L} \therefore B = \sqrt[3]{\frac{WL}{2\cdot25K}}$$

and similarly for the rest.

Molesworth (pp. 119—120, 19th ed.) gives for cast and wrought iron girders:—

Cast-Iron Girders.

D = Depth of girder in inches, including flanges.
A = Area of bottom flange in inches (*i.e.*, width × thickness).
S = Span in inches.
W = Breaking weight in tons.
Supported at both ends with load:—

$$(38.)\quad \text{On centre, } W = \frac{25\,AD}{S} \therefore D = \frac{WS}{25A}$$

$$(39.)\quad \text{Distributed, } W = \frac{50\,AD}{S} \therefore D = \frac{WS}{50\,A}$$

Area of top flange if the load is applied on the top $= \frac{A}{3}$

If applied on the bottom flange $= \frac{A}{2}$. And $D = \frac{S}{12}$ (about).

Wrought-Iron Plate Girders.

L = Span in feet.
W = Weight distributed in tons.
D = Effective depth of girder in feet.
S = Strain on top and bottom flange at centre in tons.

$$(40.)\quad S = \frac{WL}{8D} \therefore D = \frac{WL}{8S}$$

In compression, iron may be strained 4 tons; in tension, 5 tons per square inch.

Long Square Columns—length more than 30 times diameter.

W = Breaking load in tons.
B = Breadth in inches.
L = Length in feet.
K = Coefficient of rupture.

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(41.) $W = \frac{KB^4}{L^2} \therefore B = \sqrt[4]{\frac{WL^2}{K}}$

K for dry Memel = 7·81.
K for dry Oak = 10·95.

If in a damp situation as pulley frames, K must be taken rather less, say 6 and 9 respectively.

Dams, Tubbing, &c.

k = Thickness in inches.
r = External radius in inches.
T = Ultimate crushing strength in lbs. per square inch (See Table IX.).
p = Head of water in lbs. per square inch.

Cylindrical Dam, Walling, or Tubbing.

(42.) $k = r\left\{1 - \sqrt{1 - \frac{20p}{T}}\right\}$.

Spherical Dam.

(43.) $k = r\left\{1 - \sqrt[8]{1 - \frac{15p}{T}}\right\}$.

10 is taken as the factor of safety, and is allowed for in the formulæ.

See "Internal Stress in Cylindrical and Spherical Dams," by W. Steadman Aldis. Trans. N.E.I., xxxii.

TABLE IX.

Wrought-Iron	T= 38,080
Cast-Iron	T=107,520
Beech	T= 8,500
Oak	T= 10,000
Pitch Pine	T= 6,500 (?)
Brick ord. red	T= 800
Do. Stourbridge fire	T= 1,717
Sandstone	T= 2,185 to 7,884
Concrete about	T= 2,000

(Molesworth.)

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Another Formula for Cast-Iron Tubbing.

x = Required thickness in feet.
P = Vertical depth in feet.
D = Diameter of pit in feet.

$$(44.)\quad x = \cdot 03 + \frac{PD}{50{,}000.}$$

(Greenwell's "Mine Engineering.")

The following books may be consulted:—Barlow's "Strength of Materials"; Box's "Strength of Materials"; "Materials and Construction," by Campin, Weale's Series; and Molesworth's "Pocket Book of Engineering Formulæ."

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TIMBER.

THE most suitable timber for pit props, baulks, &c., is fir and pine, because—though weaker and less durable than oak, elm and some other timber—it is light, cheap, straight, and elastic.

The mining timber used in the North of England comes chiefly from Sweden, and is the product of the Scotch fir (*Pinus sylvestris*) and the spruce (*Abies communis*), known to the trade as "red and white wood" respectively. A good deal of native-grown larch (*Abies larix*) too is used, more especially for sleepers.

Beech, grown in the district, is used for nogs. Pitch pine (*Pinus rigida*) from North America, for pump spears, pulley frames, &c.

Timber Measure.

Props are bought and sold per 72 running feet, the price depending upon the diameter. Larger sizes per cubic foot, per load, or per standard. To calculate the number of cubic feet in round timber: gird the log round the middle with a string, and one fourth of the girth squared × the length = cubic content. If the log be very irregular, divide it into several lengths and measure each separately.

1 load = 40 cubic feet, unhewn timber.
" = 50 " squared "
" = 600 superficial feet, in 1 inch deals or planks.
" = 400 " $1\frac{1}{2}$ "
and so on, equal in each case to 50 cubic feet.

1 square of flooring = 100 superficial feet.

Battens are 7 inches wide, deals 9 inches, and planks 11 inches.

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1 standard	= 165 cubic feet square timber.			
"	= 150	"	partly squared.	
"	= 100	"	round.	
"	= 1500 running feet of 3 inch.			
"	= 1200	"	4	"
"	= 1000	"	5	"

A standard of timber occupies about the same space on board ship as $3\frac{3}{4}$ tons of coal; but this partly depends upon the shape of the ship.

Cost of Timbering.

This is very variable, depending upon the conditions of the mine and the price of timber.

Callon cites Grand-Combe $3\frac{1}{2}$*d.* per ton of coal. Evrard, a colliery in the Pas-de-Calais, 10·088*d.*; and one in Belgium, 1*s.* 3*d.* Drinker, quoting Rhiza, gives the consumption of 54 German mines from 1·35 to 8·58 cubic feet of timber per 100 cubic feet of coal. Average, 3·40 cubic feet.

At a colliery in Durham, using larch, the cost, in 1877, was 4·08*d.* per ton of coal worked. And during the same year, at a colliery in Northumberland, using Norway, the cost was 4·77*d.*

The following books may be consulted:—Templeton's "Workshop Companion"; Laslett's "Timber and Timber Trees"; Rattray and Mills' "Forestry and Forest Products."

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EXPLOSIVES.

General rule 12 of the Mines Act, 1887, deals with explosives. The chief points are as follows:—No explosive may be taken into the mine except in cartridges in a canister containing not more than 5lbs. Charging tools of iron or steel are forbidden, and coal may not be used for tamping. No explosive may be pressed into an insufficient hole. A charge may not be unrammed, and no hole may be bored for a charge at less than six inches from a hole where the charge has missed fire. In any place where a safety lamp is required, or which is dry and dusty, shots may only be fired by a person appointed for the purpose, who must first examine all places within 20 yards. If gas has been reported a shot may not be fired unless there is not sufficient gas at or near the place of firing to render it unsafe; or unless the explosive be of such a nature that it cannot fire gas. If the place be dry and dusty a shot may not be fired unless the place to a distance of 20 yards be watered; or, should watering damage the roof or floor, unless the explosive be of such a nature that it cannot inflame gas or dust. If the place be dry and dusty and be on, or contiguous to, a main haulage road, a shot may not be fired unless both the last-mentioned conditions have been observed; or else such one of them as may be applicable, and also all workmen have been removed from the seam and from all seams communicating with the shaft upon the same level, except the shot firers and such others not exceeding ten as are necessarily employed in attending to furnaces, machinery, signals, horses and inspection.

The Explosives Act, 1875, is too long to abstract; but a few points may be mentioned. No explosive may be kept for sale without a licence. Not more than 20 lbs. of gunpowder, and 150 lbs. of safety cartridges (as ordinary shots) or 15 lbs. of any other explosive, or in lieu of any less amount of gunpowder not so kept, half that amount of other explosive may be kept for private use without a licence. Cartridges for blasting may not be made in a private house; they must be bought ready made, or manufactured in a

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workshop in connection with, but detached from, (25 to 100 yards) the store. The store must not be situated in a mine or quarry where persons are employed; or within a certain distance (the exact distance depending upon the quantity of explosive for which it is licensed; but 200 yards is the maximum, and should houses, etc., be subsequently built within the prescribed zone, the store must be removed), of houses, workshops, railways, roads, fires, etc. It must be substantially built of brick, stone, or concrete; or be excavated in solid rock, earth, or mine refuse not liable to ignition; and so made and closed as to prevent unauthorised persons from having access. There must be no exposed iron, steel, or grit in the building. Nothing may be kept in the store but the explosive and the necessary implements, which must be made of copper, wood, or brass. Lightning conductor required, unless the store be underground or licensed for less than 1,000 lbs. of gunpowder. No person under 16 to enter, except under supervision of a grown-up person. The quantity of gunpowder that may be kept varies from 300 to 4,000 lbs., according to the character of the store. If licensed for mixed explosives, 300 to 4,000 lbs. of powder, and, in addition, 1,500 to 20,000 lbs. of safety cartridges (the cases are included in the weight); in lieu of each lb. of powder, ½ lb. of any other explosive may be kept; and, in addition to each lb. of powder, 5 lbs. of safety fuzes. A copy of the rules must be affixed to the store. There are several common sense regulations, such as no smoking allowed, etc. See "Guide Book to the Explosives Act," by Major Majendie.

All explosives exert an equal force in every direction.

An explosive takes effect along the line of least resistance. In a homogeneous material this will be the shortest line from the charge to the face, and will be most efficient when at right angles to the shot-hole, and least efficient when it coincides with the axis of the shot-hole. The quantity required varies as the cube of the line of least resistance. A cartridge, one inch diameter, and 38 inches long, contains one lb. of powder. The chemical changes that take place when powder is fired, may be roughly represented as follows:—

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(45.) $S + 3C + 2KNO_3 = 3CO_2 + N_2 + K_2S.$

Gunpowder fires at about 482° Fahr. and expands to at least 1,500 times its original volume.

(Miller's "Inorganic Chem.")

TABLE X.

Explosive.	Composition.	Heat Evolved	Vol. of Gas per lb.	Product indicating Blasting Effect.
Gunpowder.	Potassium Nitrate......74·70 Sulphur..................12·45 Charcoal ....12·25	1,093	3·61	3,945
Nitro-glycerine.	$C_3H_5O_33(NO_2)$	2,372	11·41	27,064
Dynamite.*	Nitro-glycerine.........75 Silica 25	1,780	8·56	15,236

(Proc. I.C.E., XLIII.)

Tons of coal got in 1875 per lb. of powder employed both in hewing and stone work—

Northumberland Steam Coal	5·95
Northumberland House, Coking Coal, &c .	25·80
Durham House and Gas Coal . . .	21·00
Durham Coking Coal, &c. . . .	23·99
Cumberland	21·42
Whole district . . .	9·97

(J. B. Atkinson.)

In Pennsylvania in 1881 and 1882, 2·23 tons only; but the seams lie at high angles, and there is much stone work.

Substitutes for Explosives.

The wedge, wedge and feather, Macdermott's multiple wedge and feather, Macdermott's screw wedge, Macnab's

* Dynamite, if used with water tamping, will get coal in good condition; and has this advantage over gunpowder used with water tamping, that a blown out shot will not fire gas. (See Report of Accidents in Mines Commission, 1886.)

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hydraulic cartridge, the Haswell Mechanical Coal-getter, the Seaton Delaval Detacher, and many others. See Trans. N.E.I., ii., xii., xiv., xix., xxiii., xxxiii.

Lime Cartridges.

Quick lime + water in excess = slaked lime + steam.

(46.) $CaO + H_2O + Aq = CaH_2O_2 + Aq.$

Mountain limestone is calcined, ground to a fine powder, and formed into cartridges 2½ inches diameter, with a groove along the side by means of an hydraulic pressure of forty tons. The shot-holes being drilled, an iron tube half-an-inch in diameter, having a small external groove on the upper side, and provided with perforations, is inserted along the whole length of the bore-hole. This tube is enclosed in a bag of calico, covering the perforations at one end, and has a tap at the other. The cartridges are then inserted and tamped. A force pump is connected with the tap by means of a flexible pipe and water, equal in bulk to the quantity of lime used, is forced in. The water being driven to the far end of the shot hole through the tube, escapes along the groove, and through the perforations and the calico, flowing towards the tamping into the lime and driving out the air before it. The tap is then closed. The pressure of steam generated by the usual charge of seven cartridges is 2,850 lbs., and the expansion of the cartridge about five times its original size.

The advantages claimed for this system are:—Absolute immunity from explosion of gas, there being no fire or flame. There is no smoke or noxious smell. The roof is not shaken, and the coals in falling produce less dust. Skilled labour is unnecessary, and the coal can be got with much less exertion than by wedging. Major Paget Mosley. Trans. Midland Inst. of Mining, Civil, and Mechanical Engineers. Vol. VIII., pp. 87—93.

It has been averred that the heat given off is sufficient to ignite gas, but Abel says that the maximum heat produced by the slaking of the lime is 700 degrees, whereas it takes a temperature of 2,000 degrees to ignite gas. On the other hand, coal dust ignites at a temperature much below 700 degrees Fah.

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MACHINERY.

Nature and Uses of Machinery.

The use of machinery is to transmit and modify motion and force. In the action of a machine, the three following things take place :—1st. Some natural *source of energy* communicates *motion* and *force* to a part of the mechanism called the *prime mover*. 2nd. The motion and force are transmitted from the prime mover through the train of mechanism to the *working piece*; and, during that transmission, the motion and force are modified in amount and in direction, so as to be rendered suitable for the purpose to which they are applied; and 3rd, The working piece, by means of its motion, or of its motion and force combined, accomplishes some useful purpose. (Rankine, M.M., p. 1.)

Some of these terms require explanation, viz. :—

Force may be defined as an action between two bodies, causing or tending to cause, rest or motion. The British unit of force is the force required to support a weight of one lb. at London, or roughly, at any other place on the globe. *Work* may be defined as the combination of force and motion. The unit of work is a force of one lb. exerted through a distance of one foot. *Power* may be defined as the speed of doing work. The unit of power is a force of one lb. exerted through a distance of one foot in one minute.

A horse-power is equal to 33,000 of the above units of power.

It is sometimes convenient to use the second, or the hour as the unit of time instead of the minute. One British horse power then is :—550 foot lbs. per second = 33,000 foot lbs. per minute = 1,980,000 foot lbs. per hour.

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We have then the following rules :—

(47.) Units of Work=Force in lbs. × Distance in feet.

(48.) $\text{Units of Power} = \dfrac{\text{Force in lbs.} \times \text{Distance in feet.}}{\text{Time in minutes.}}$

(49.) $\text{Units of Horse-power} = \dfrac{\text{Force in lbs.} \times \text{Distance in feet.}}{\text{Time in minutes} \times 33{,}000.}$

Energy may be defined as *the power of doing work.*

Heat is a form of energy. The unit of heat (or thermal unit) is, approximately, the quantity of heat required to raise one lb. of water one degree Fahr. Different bodies require very different quantities of heat to effect in them the same change of temperature, and the quantity of heat that one lb. of a body requires to raise its temperature one degree is called the specific heat of that body.

TABLE XI.

SPECIFIC HEATS.

			At constant pressure.	At constant volume.
Water ... 1·0000	Air	Air	0·2379	0·1686
Cast Iron ... 0·12983	Carbonic Acid	Carbonic Acid	0·2164	0·1711
Wrought Iron ... 0·11379	Carbonic Oxide	Carbonic Oxide	0·2479	0·1763
Copper ... 0·09515	Vapour of Water	Vapour of Water	0·4750	0·3640
Silver ... 0·05701	Nitrogen	Nitrogen	0·2440	0·1727
Tin ... 0·05695	Sul. Hydrogen	Sul. Hydrogen	0·2423	0·1833
Gold ... 0·03244	Hydrogen	Hydrogen	3·4046	2·4046
Lead ... 0·03140	After-damp	After-damp	0·268	0·196
Coal ... 0·2777	Oxygen	Oxygen	0·2182	0·1555
Coke ... 0·20085				
Calcium ... 0·1670				
Slaked Lime ... 0·223				

(Regnault.)

We have, then, the following rule :—

The units of heat required to raise a given body, a given number of degrees=the weight of the body × the number of degrees × the specific heat of the body.

If, therefore, U=Units of heat.

D=Degrees Fahr. the body is heated.

S=Specific heat of body. (See Table XI.)

W=Weight of body in lbs.

(50.) $U = WDS \therefore D = \dfrac{U}{WS}$.

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Connexion between heat and work.—One unit of heat = 772 units of work. A lb. of coal yields about 14,000 units of heat. An engine, therefore, consuming one lb. of coal per hour, should develop $\frac{14,000 \times 772}{33,000 \times 60} = 5\frac{1}{2}$ horse-power nearly.

One lb. of marsh gas yields about 23,550 units of heat. One lb. of hydrogen about 62,000. One lb. of illuminating gas about 22,000. Electricity is a form of energy, and may be converted into heat as in the electric light, or into work as in an electric engine. One lb. of zinc reacted upon by sulphuric acid in a battery yields 1,018 units of work.

Energy is indestructible, but in converting one form of energy into another, there is always practically great waste. For example: One lb. of coal, though it yields 14,000 units of heat, and should, therefore, give us $5\frac{1}{2}$ horse-power, will only give, in the best steam-engines, about $\frac{1}{2}$ of one horse-power.

The principal sources of energy are ;—Food, fuel, heads of water, and the wind.

The principal prime movers are ;—Men and horses, steam-engines, water-wheels, and wind-mills.

The train of mechanism which connects the prime mover with the working piece may consist of wheels, levers, spears, ropes, a fluid, electricity, etc.

The working piece may be a bit, pump, cage, tub, etc.

We see then that *machinery* enables us to make use of the *energy* Nature provides.

The following books may be consulted:—The Conservation of Energy, Balfour Stewart; Energy in Nature, Carpenter; Heat a Mode of Motion, Tyndall.

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PRIME MOVERS.

A. Men and Horses.

Food is the source from which men and horses obtain their energy; their efficiency is very great as compared with the efficiency of a steam-engine, about 27 per cent. of the units of heat yielded by a horse's food being turned into mechanical energy or work, against about 10 per cent. in a steam-engine.

Mr. Hunting is the great authority in the North of England on the feeding and management of colliery horses, and his views are embodied in a paper published in the Trans. N.E.I., vol. xxxii. Table XII., extracted from this paper, shews that beans and peas contain the largest pro-

TABLE XII.

—	Water.	Woody Fibre.	Starch, Gum, Sugar, & Fat.	Nitrogenous matter.	Ash or Saline.	TOTAL.	REMARKS.
Beans or Peas...	14·5	10·0	46·0	26·0	3·5	100·00	Constipating.
Barley	13·2	13·7	56·8	13·0	3·3	100·00	Not more than 25°/₀ of the total corn mixture.
Oats.........	11·8	20·8	52·0	12·5	3·0	100·10	Form with hay a good food; but costly.
Maize	13·5	5·0	67·8	12·29	1·24	99·83	Laxative.
Hay..... ...	14·0	34·0	43·0	5·0	5·0	101·00	50 lbs. old land hay=60 lbs. of new land hay.
Carrots ...	85·7	3·0	9·0	1·5	0·8	100·00	
Bran	...	...	...	...	...	...	Laxative, and useful as a bulky palatable article, but has little feeding value.
Linseed ...	...	...	...	...	...	...	Laxative.

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portion of nitrogenous matter; whilst oats, maize, and barley are of equal feeding value per stone. Beans or peas, being constipating, must be mixed with maize or bran. The quantity of food must be regulated by the amount of work; but about 100 lbs. of mixed corn, crushed and mixed with about 56 lbs. of chopped hay, will form an average week's provender for each horse. He considers that beans (or peas) and hay with either, 1, Oats and bran; 2, Barley and bran; 3, Oats and maize; 4, Maize—will form equally good mixtures, and we must be guided in our selection by price.

A horse should be put down the pit at about 5 to 7 years of age; should travel from 14 to 16 miles per day, in a fairly level mine at a walking pace, and last about 7 years. One horse-keeper is required for 12 horses, or for 16 ponies. A pony should not be put into the pit under 3 years of age.

The cost of feeding, etc., is very variable; but we may say, roughly, that to maintain a stud of 100 horses (or their equivalent in ponies) we must expend yearly:—

	£	s.	d.
Provender @ 10/- per horse per week	2,600	0	0
Veterinary surgeon	150	0	0
Head horse-keeper @ 25/- per week	65	0	0
8 assistant „ @ 20/- „	416	0	0
2 loftmen @ 18/- per week	93	12	0
Shoeing (labour and materials) ...	120	0	0
Saddlery („) ...	210	0	0
Drugs	10	0	0
Renewals, less sales	350	0	0
Candles, brushes, clipping, etc. (say)	50	8	0
Total	£4,065	0	0

equal to £40 13*s.* 0*d.* per horse per annum.

But each horse will require a boy to drive it; and in the North of England the horse-keepers and loftmen will receive free houses and fire-coal. So that the total cost of each horse will amount to nearly £60 a year.

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The following weights and measures are used:—

14 lbs. = 1 stone; 4 pecks = 1 bushel; 8 bushels = 1 quarter.

A bushel of oats should weigh not less than 42 lbs.

"	barley	"	56	"
"	maize	"	60	"
"	beans	"	63	"
"	peas	"	63	"

From Table XIV. we see that a draught horse, under conditions somewhat similar to those which are found in mines, can do $120 \times 3 \cdot 6 \times 60 = 25{,}920$ foot lbs. per minute during a shift of eight hours. This is rather less than the power of a pit horse, as calculated from experiment by Mr. Nicholas Wood, Trans. N.E.I., iii.

TABLE XIII.

WORK OF A MAN AGAINST KNOWN RESISTANCES.

KIND OF EXERTION.	R. lbs.	V. ft. per sec.	$\frac{T''}{3600}$ hours per day.	R. V. ft.-lbs. per sec.	R.V.T. ft.-lbs. per day.
1. Raising his own weight up stair or ladder.........	143	0·5	8	72·5	2,088,000
2. Hauling up weights with rope, and lowering the rope unloaded	40	0·75	6	30	648,000
3. Lifting weights by hand..	44	0·55	6	24·2	522,720
4. Carrying weights up stairs, and returning unloaded.	143	0·13	6	18·5	399,600
5. Shovelling up earth to a height of 5 ft. 3 in.	6	1·3	10	7·8	280,800
6. Wheeling earth in barrow up slope of 1 in 12, ½ horiz. veloc. 0·9 per ft. sec. and returning unloaded	132	0·075	10	9·9	356,400
7. Pushing or pulling horizontally (capstan or bar)	26·5	2·0	8	53	1,526,400
8. Turning a crank or winch	12·5	5·0	?	62·5	...
	18·0	2·5	8	45	1,296,000
	20·0	14·4	2 min.	288	...
9. Working pump	13·2	2·5	10	33	1,188,000

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TABLE XIV.

WORK OF A HORSE AGAINST KNOWN RESISTANCES.

(Three 14-hand ponies = two horses; and two small ponies = one horse.)

KIND OF EXERTION.	R.	V.	$\frac{T''}{3600}$	R.V.	R.V.T.
1. Cantering and trotting drawing a light railway carriage (thorough-bred)	min. 22½ mean 30½ max. 50	14⅜	4	447½	6,444,000
2. Horse drawing cart or boat walking (draught horse)	120	3·6	8	432	12,441,600
3. Horse drawing a gin or mill walking..............	100	3·0	8	300	8,640,000
4. Ditto trotting	66	6·5	4½	429	6,950,000

Explanation.—R., resistance; V., effective velocity = distance through which R is overcome ÷ total time occupied, including the time of moving unloaded, if any; T″, time of working, in seconds per day; $\frac{T''}{3600}$, same time, in hours per day; R.V., effective power in foot-pounds per second; R.V.T., daily work in foot-pounds.

The weight of the man or horse is not included, except in No. 1 of the first Table. (Rankine, S. E.)

The annual cost of a pit horse, including depreciation and driver's wages, is about £60.

B. Hydraulic Motors.

A head of water is the source from which hydraulic motors receive their energy; they are the most efficient of all prime movers, utilising about 80 per cent. of the units of work stored up in the head of water, as compared with 27 per cent. and 10 per cent. utilised by horses and steam-engines.

A head of water can be made use of in one or other of the following ways, viz.:—

1st. By its weight, as in the water-balance, and overshot wheel.

2nd. By its pressure, as in the hydraulic engine.

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3rd. By its impulse, as in the undershot wheel.
4th. By a combination of the above.

Bearing in mind our definition of the unit of power, see p. 32, we see that the maximum units of power a head of water can yield are equal to the volume in cubic feet falling per minute × pressure in lbs. per square foot, *i.e.*, the volume, × the weight in lbs. per square foot of the column or head of water.

This general statement is true for all fluids—water, steam, air, etc.—and may be expressed as follows :—

If V=Volume of any discharged fluid in cubic feet.
P=Effective Pressure at which it is discharged in lbs. per square foot.
U=Units of work in foot lbs. that can be got from the fluid's discharge without expansion.

(51.) U=PV.

In speaking of water, however, it is generally more convenient to say :—

If W=Weight of water falling per minute in lbs.
H=Head of water in feet.
U=Units of work in foot-lbs. per minute.

(52.) U=WH.

The amount of rainfall is an important factor that must be taken into account in calculating the water-power of any place. The average annual rainfall in different parts of Britain ranges from 22 inches to 140 inches. At Newcastle it is from 26 to 27 inches.

(53.) One inch in depth per acre weighs 101 tons.

C. Wind-mills.

The wind is the source from which wind-mills derive their energy ; their efficiency is about 29 per cent. (Smeaton.)

The power of a wind-mill might be calculated from the rule already given, viz. :—(51.) U=PV.

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In which U=units of work in foot-lbs. per minute.
P=pressure of the wind in lbs. per sq. foot.
V=volume in cubic feet of the cylinder of wind passing the sails each minute, the diameter of the cylinder being equal to the diameter of the sails.

But that, the sails being in motion, the value of P cannot easily be obtained. If the sails were stationary, the wind-pressure could be found as follows:—

Let V_1=velocity of the wind in miles per hour.
P=pressure in lbs. per sq. foot.

$$(54.)\quad P=\frac{V_1^2}{200}.$$

In these circumstances, the following rule should be used:—

U=units of work in foot lbs. per sec.
W=weight in lbs. of the cylinder of wind passing the sails each second, the diameter of the cylinder being equal to the diameter of the sails.
V=velocity of wind in feet per sec.
HP=horse-power.

$$(55.)\quad U=\frac{WV^2}{64}.$$

$$(56.)\quad HP=\frac{WV^2}{64\times 550}.$$

$$(57.)\quad \text{Effective horse-power}=\frac{0{\cdot}29WV^2}{64\times 550}.$$

The average velocity of the wind in England is about 13 miles an hour.

D. The Steam Engine.

Fuel is the source from which the steam-engine derives its energy. One lb. of very good coal yields about 14,000 units of heat = 14,000 × 772 = 10,808,000 units of work. The best steam-engines consume about 2 lbs. of coal per effective HP per hour = 14,000 × 2 × 772 = 21,616,000 units

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of work; but one horse-power per hour is only $33,000 \times 60 = 1,980,000$ units of work. The efficiency, therefore, of the best engines is only :—

(58.) $\frac{1,980,000 \times 100}{21,616,000} = 9 \cdot 15$ per cent. of the total energy stored up in the coal.

Why is this so?—The loss is in part due to heat uselessly expended in warming the sides of the boiler, steam-pipes, cylinders, etc., and air in contact with them; also, to imperfections in the machinery. These may be in part removed with improvements in machinery. For example, the following Table, quoted from *Coal: its History and Uses*, p. 227, illustrates the large saving of heat effected in the past by improvements in the steam-engine.

TABLE XV.

100 UNITS OF HEAT SUPPLIED.

DESCRIPTION OF ENGINE.	Heat transmitted to Boiler.	Heat used in doing Work.
Unjacketed..	54	5·9
Jacketed..	54	6·6
Steam superheated	60	8·7
Working with Siemen's Regenerator.........	60	10·0
Engines of H.M.S. "Briton"	—	11·1

But the nature and properties of steam account for a very large proportion of the loss, and this cannot be recovered.

It has been estimated that 20 per cent. of the energy stored in the coal passes up the chimney, 10 per cent. is lost by radiation, 10 per cent. is turned into work, and the remaining 60 per cent. is wasted.

If T_1 = Absolute temperature of steam on admission, *i.e.*, temp. Fahr. + 459°.

T_2 = Absolute temperature of exhaust steam, *i.e.*, temp. Fahr. + 459°.

E = Maximum efficiency of a theoretically perfect steam-engine.

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(59.) $E = \frac{T_1 - T_2}{T_1}$.

The Actual or Indicated horse-power is the measure of the capacity of the engine for doing work :—

If, therefore, A = Net area of piston in square inches.
P = Effective pressure of steam in lbs. per square inch.
S = Mean speed of piston in feet per minute.
HP = Horse-power.

(60.) $HP = \frac{APS}{33{,}000} \therefore A = \frac{33{,}000\,HP}{PS}$.

In a *high pressure non-condensing engine* P = the pressure of the steam in the boiler, less the pressure of the atmosphere, *i.e.*, P = the reading of the steam-gauge.

The low-pressure condensing-engine.—The actual horse-power is given by formula (60), but P now is equal to the pressure of the steam in the boiler, less the pressure of the vapour in the condenser, *i.e.*, P = reading of the steam-gauge in lbs. + half the reading of the vacuum gauge in inches.

Engines working with expansion.—The actual horse-power is given by formula (60), but in non-condensing engines working with expansion, P is given by the following rule :—

MP = Mean pressure.
PB = Boiler pressure = reading of steam-gauge + 15 lbs.
L = Total length of stroke.
Q = Length of stroke before cut off.

(61.) $MP = \frac{PBQ}{L}\left(1 + \text{Hyp. log. } \frac{L}{Q}\right)$.

Hyp. log. $\frac{L}{Q}$ will be found in the Table, see page 132.

Finally P = MP − 15. And in condensing engines working with expansion P is equal to MP as obtained from Formula (61), less the pressure of the vapour in the condenser.

The compound engine prevents shocks and cooling. See table, pages 50 and 51, for the fall in temperature corresponding with any given fall in pressure. To calculate the

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horse-power of a compound engine, treat it as if it were a one-cylinder engine, of the size of the large cylinder of the compound engine, and use the preceding formulæ (neglecting loss due to steam passages).

By means of the above formulæ, the size of engine required to do any given work can be calculated, the pressure of steam and speed of piston being known. In the case of a compound engine, find the size of a single cylinder engine required to do the work, and add to it a small cylinder proportioned as follows:—

If A = Area of piston of large cylinder.
a = Area of piston of small cylinder.
R = Ratio of expansion.

(62.) $$a = \frac{A}{\sqrt{R}}$$

Half the total expansion should be carried out in each cylinder.

The Indicator is used for finding the horse-power when greater accuracy is required. It also enables the Engineer to find out and localise any defects in the working of an engine.

Nominal horse-power is an expression used for commercial purposes only, and gives merely the size of the engine.

If D = Diameter of cylinder in inches.
NHP = Nominal horse-power.

(63.) $NHP = \frac{D^2}{10}$ (High pressure or non-condensing engine where P = 21 and S = 200.)

(64). $NHP = \frac{D^2}{30}$ (Low pressure or condensing engine where P = 7 and S = 200.)

The effective horse-power, or the useful work done, is a very variable quantity, depending upon the efficiency of the engine, the way in which it is connected with its work, the nature of the work, etc., etc. Speaking roughly, the effective horse-power of the engines used at our mines is about one half of their actual horse-power.

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Proportions of engines.—See Molesworth, p. 325, xix. Ed.

If A = Transverse sectional area of a cylinder.
D = Diameter of a cylinder.
C = Circumference of a cylinder.
V = Volume of a cylinder.
L = Length of stroke.

(65.) $A = {\cdot}7854\, D^2 \therefore D = \sqrt{\frac{A}{{\cdot}7854}}$

(66.) $C = 3{\cdot}1416\, D \therefore D = \frac{C}{3{\cdot}1416}$.

(67.) $V = {\cdot}7854\, D^2 L$.

The cost for the repairs of colliery engines has been estimated at 5*s.* per horse-power per annum. See Trans. N.E.I. xvii.

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BOILERS.

Strength of Boilers.

Steam expands equally in all directions; therefore the pressure is equal in all directions. It is reasonable, therefore, to suppose that the strongest shape for a boiler is that figure which is similar to itself in all directions, viz., a sphere. As, however, a spherical boiler would be inconvenient, a cylindrical boiler, with hemispherical ends, is the strongest practical form.

1st. *Strength to resist internal pressure.*—Let a cylindrical boiler be L inches long, D inches diameter, and let P = pressure of steam in lbs. per sq. in. Let T = the tensile strain in lbs. per linear inch to which the boiler plates are subjected.

Then the total force tending to tear asunder the sides (*i.e.*, to open the horizontal seams), is equal to the pressure of the steam in lbs. per sq. in. × area in sq. inches over which it is exerted = PDL. And this is resisted by the tensile strength of the side plates, which are 2L inches in length. The tensile strain upon each linear inch of the side plates (*i.e.*, upon the horizontal seams) is, therefore,

$$(68.)\ T = \frac{PDL}{2L} = \frac{PD}{2}.$$

In the same way, the strain per linear inch upon the end plates (*i.e.*, upon the vertical seams) is

$$(69.)\ T = \frac{\cdot 7854 PD^2}{3\cdot 1416 D} = \frac{PD}{4}.$$

We see, then, that the horizontal seams are subjected to double the strain upon the vertical seams. For this reason, boiler-plates are sometimes rolled in rings, so that the boiler may have no horizontal seams at all.

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The ultimate tensile strength of ordinary iron boiler plate is 20 tons per sq. inch; which is reduced by single riveting to about 25,000 lbs., and by double riveting, to about 30,000 lbs. We deduce from these facts, and from formula (68), the formulæ (25) and (26).

The use of steel plates for colliery boilers is hardly yet established. We may, however, take their ultimate tensile strength at 30 tons per sq. inch; and the reduction of strength due to riveting the same as in iron plates. From these data formulæ (27) and (28) are calculated.

2nd. *Strength to resist external pressure.*—The flues are subjected to external pressure. See formula (29). Where they are strengthened by rings, L = length between rings.

The weight of a boiler may be calculated from the follow ing rule, viz.:—Weight in lbs. = surface in sq. ft. × 6 for plates $\frac{1}{8}$-inch.

3rd. *Practical remarks on iron boilers.*—Generally in the North, $\frac{3}{8}''$ plates are used for sides and hemispherical ends; rivets, $\frac{3}{4}'' \times 1\frac{3}{4}''$, placed $2''$ apart, $1\frac{1}{8}''$ lap. For flat ends, $\frac{5}{8}''$ to $\frac{6}{8}''$ plates strengthened with gusset stays or rods. Tubes, $\frac{3}{8}''$ to $\frac{4}{8}''$. Diameter of low pressure boilers, 6 to 10 ft.; high pressure, 4 to 6 ft.

Boiler Fittings.

Man-hole, weighted safety-valve, spring safety-valve, steam-gauge, float, and glass water-gauge, sludge steam and feed-pipes, blow-off cock, damper, etc.

The steam-gauge gives the pressure of the steam in the boiler, less the pressure of the atmosphere.

The lever safety-valve:—

P = Pressure of steam in lbs. per square in., less atmospheric pressure.

L = Length of lever from fulcrum to weight in inches.

W = Weight of weight in lbs.

W′ = Weight of lever in lbs.

W″ = Weight of valve in lbs.

D = Distance of the centre of gravity of the lever from the fulcrum in inches.

A = Area of valve in square inches.

I = Length of lever between fulcrum and valve in inches

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$$(70.)\ P = \frac{\frac{WL}{I} + \frac{W'D}{I} + W''}{A}$$

Explosions.

Explosions may be produced by—1st. Defective, or neglected, or tampered-with safety-valves, producing excessive pressure. 2nd. Defective water supply. 3rd. Incrustation, producing over-heating. 4th. Corrosion, weakening the boiler.

The remedies for 1st and 2nd are obvious.

3rd. *Incrustation* (as distinguished from mere sediments due to dirty water, which are easily blown out, or gathered up, by means of sediment collectors) is due to the presence of salts in the feed water (carbonates and sulphates of lime and magnesia for the most part), which are precipitated when the water is heated, and form hard, crystalloid deposits upon the boiler plates. The plates, being no longer in contact with water, are over-heated, and destroyed.

Where the quantity of these salts is not very large (12 grains per gallon, say) boiler doctors will be found very effective. They either form with the salts other salts soluble in hot water; or precipitate them in the form of soft mud, which does not adhere to the plates, and can be sludged out from time to time. The selection of a doctor must depend upon the composition of the water, and to be thoroughly satisfactory it should be introduced regularly with the feed, not once for all at each periodic cleaning of the boiler.

Examples:—

The deposition of carbonate of lime can be prevented by dissolving sal-ammoniac in the water (it will, however, damage the plates). The chloride of calcium and carbonate of ammonia produced being soluble in water:—

$$\begin{array}{ccccccc} \text{Carbonate of lime} & + & \text{Sal-ammoniac} & = & \text{Chloride of calcium} & + & \text{Carbonate of ammonia.} \\ (71.)\ CaCO_3 & + & 2NH_4Cl & = & CaCl_2 & + & (NH_4)_2CO_3. \end{array}$$

Sulphate of lime by carbonate of soda. The sulphate of

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soda produced is soluble in water; and the carbonate of lime falls down in grains, does not adhere to the plates, and may, therefore, be blown out or gathered into sediment collectors:—

$$\begin{array}{lcccccccc} & \text{Sulphate of lime} & + & \text{Carbonate of soda} & = & \text{Sulphate of soda} & + & \text{Carbonate of lime.} \\ (72.) & CaSO_4 & + & Na_2CO_3 & = & Na_2SO_4 & + & CaCO_3 \end{array}$$

Sodium phosphate will decompose the sulphates of lime and magnesia:—

$$\begin{array}{lcccccccc} & \text{Sulphate of lime} & + & \text{Sodium phosphate} & = & \text{Calcium phosphate} & + & \text{Sulphate of soda} \\ (73.) & CaSO_4 & + & Na_2HPO_4 & = & CaHPO_4 & + & Na_2SO_4 \end{array}$$

$$\begin{array}{lcccccccc} & \text{Sulphate of magnesia} & + & \text{Sodium phosphate} & = & \text{Phosphate of magnesia} & + & \text{Sulphate of soda} \\ (74.) & MgSO_4 & + & Na_2HPO_4 & = & MgHPO_4 & + & Na_2SO_4 \end{array}$$

Where the quantity of salts is large, boiler doctors are not of much use. Some other source of supply must be sought, or the bad water purified before it is allowed to enter the boilers. And as the damage done, especially to locomotive boilers, by unsuitable water is enormous, it is worth while going to considerable expense to obtain a good supply.

Pure water may be obtained by collecting rain, or condensing steam by means of surface condensers. The water thus obtained should be mixed with a little bad water, as, undiluted, pure water corrodes iron; or, after each periodic cleaning, the bad may be used for a day or two to put a skin upon the plates.

The carbonate of lime and magnesia may be precipitated either by heating the water or by mixing milk of lime (Porter-Clark process) with it, the water being then filtered. And Maxwell-Lyte and Maignen have each invented a process for dealing with the sulphates upon a large scale.

4th. *Corrosion* may be produced by the use of pure water, or by the presence of acids in the water, and, perhaps, in the engine cylinder, by the action of high pressure steam upon the grease, resulting in the production of fatty acids.

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The remedy for the first has been pointed out above. Acid water may be neutralised by the addition of lime.

Horse-Power of Boilers.

1st. *Nominal horse-power* relates more to the size than to the power of the boiler.

Experience shows that 1 square yard of effective heating surface, and from 0·75 to 1·0 square foot (according to quality of coal), of fire-grate are required for each cubic foot of water at 60° evaporated per hour into steam of any pressure, and this is considered to be equal to one NHP. In a flue boiler this involves the consumption of about 7 to 9 lbs. of good steam coal, or about 12 lbs. of rough small. The consumption of fuel depends principally upon the draught:—

A Cornish boiler, with slow combustion and very sluggish draught, consumes about 5 lbs. of good steam coal per square foot of grate per hour.

A Cornish or Lancashire boiler, with good chimney draught, about 14 lbs.

A cylindrical boiler, with good chimney draught, about 20 lbs.

A locomotive boiler, and others with strong steam blast, 100 lbs.

If NHP = Nominal horse-power.
  A = Area of effective heating surface in square yards.
  F = Fire-grate area in square feet.

(75.) $NHP = \sqrt{AF}.$

In a boiler fired externally, A, the effective heating surface, is about $\frac{2}{3}$ of the whole surface of the boiler. In the case of flue boilers, add to the above $\frac{1}{3}$ of the surface of the flues.

If L = Length of a boiler or any cylindrical vessel in feet.
  D = Diameter do. do.
  S = Surface of the sides in square feet.

(76.) $S = 3{\cdot}1416DL$

2nd. *Actual horse-power*, *i.e.*, the ability of a boiler to supply an engine working with a given indicated horse-

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power, is not so easily estimated, the required size depending upon the kind of engine, the pressure of steam, quality of the coal, skill of the fireman, &c. Roughly speaking, the boilers about our collieries, viz., egg or flue boilers supplying non-condensing engines, working with but little expansion, and at pressures not more than 40 lbs., will give an actual horse-power $1\frac{1}{2}$ times their nominal horse-power. Where high pressure, condensation, or much expansion are used, boilers may be worked to four times their NHP.

If the consumption and pressure of the steam are known, as in the case of designing a boiler to supply any given engine, find the cubic feet of water that must be evaporated per hour from Table XVI. This will be the NHP of the boiler required, and the size, therefore, can be got from formula (75).

This table also shows the amount the steam will fall in temperature from the beginning to the end of the stroke when used expansively.

TABLE XVI.

SHOWING PRESSURE, TEMPERATURE, WEIGHT, VOLUME, TOTAL HEAT, AND LATENT HEAT OF SATURATED STEAM.

Total Pressure. Lbs.	Temperature, Fah.	Weight in Ozs. per Cubic Foot.	Volume compared with Volume of Water that has produced it.	Total Units of Heat per lb. from 32°.	Latent Heat per lb.
10	194	0·4208	2,375	1,141	979
11	198	0·4608	2,167	1,143	976
12	202	0·5008	1,994	1,144	973
13	206	0·5408	1,846	1,145	971
14	210	0·5808	1,720	1,146	968
15	213	0·6208	1,609	1,147	965
16	217	0·6608	1,512	1,148	963
17	220	0·7008	1,427	1,149	961
18	223	0·7408	1,350	1,150	959
19	226	0·7792	1,282	1,151	958
20	228	0·8192	1,220	1,152	956
21	231	0·8576	1,165	1,153	953
22	234	0·8976	1,113	1,153·5	951
23	236	0·9376	1,067	1,154	950
24	238	0·9760	1,024	1,155	948
25	240	1·0144	985	1,156	946
26	243	1·0544	948	1,156·5	945

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TABLE XVI.—*continued.*

Total Pressure. Lbs.	Tempera-ture, Fah.	Weight in Ozs. per Cubic Foot.	Volume compared with Volume of Water that has produced it.	Total Units of Heat per lb. from 32°.	Latent Heat per lb.
27	245	1·0928	915	1,157	943
28	247	1·1312	883	1,157·5	942
29	249	1·1696	854	1,158	940
30	251	1·2080	827	1,159	939
31	253	1·248	801	1,159·5	938
32	254	1·286	767	1,160	936
33	256	1·325	755	1,160·5	935
34	258	1·360	734	1,161	934
35	260	1·400	714	1,161·5	933
36	261	1·438	695	1,162	931
37	263	1·477	677	1,162·5	930
38	264	1·515	660	1,163	929
39	266	1·553	644	1,163·5	928
40	268	1·590	628	1,164	927
41	269	1·628	614	1,164·5	926
42	271	1·665	600	1,165	925
43	.272	1·704	587	1,165·5	924
44	273	1·741	574	1,166	923
45	275	1·779	562	1,166·5	922
46	276	1·816	551	1,166·8	921
47	277	1·853	539	1,167	920
48	279	1·891	529	1,167·5	919
49	280	1·928	519	1,167·8	918
50	281	1·965	509	1,168	917
51	283	2·001	499	1,168·5	916
52	284	2·038	490	1,168·8	915
53	285	2·075	482	1,169	914
54	286	2·112	473	1,169·5	913
55	287	2·149	465	1,169·8	912
56	288	2·185	457	1,170	911·5
57	290	2·222	450	1,170·5	911
58	291	2·259	443	1,170·8	910·5
59	292	2·294	436	1,171	910
60	293	2·331	429	1,171·5	909·5
65	298	2·512	398	1,173	906
70	303	2·689	372	1,174 8	901
75	308	2·867	349	1,176·5	898
80	312	3·043	329	1,177·8	895
85	316	3·217	311	1,179·2	891
90	320	3·390	295	1,180·5	888
95	324	3·560	281	1,181·5	885·7
100	328	3·728	268	1,182·5	883·7

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Surface condensers.—For ordinary colliery engines (*i.e.*, for engines working at pressures of about 40 lbs. and with very little expansion), for each indicated horse-power, 4 square feet of tube surface are required, and $2\frac{1}{2}$ gallons of cooling water per minute.

Injector condensers.—To the quantity of water theoretically required about 30 per cent. should be added.

Let Q = lbs. of condensing water theoretically required per lb. of steam to be condensed.
H = Total heat of exhaust steam (see Table XVI.).
T = Temperature of water of condensation.
t = Temperature of condensing water.

Then :—

(77.) $Q = \frac{H - T.}{T - t}$

The cost of repairs per annum is (roughly), for :—
An egg-ended boiler, £13.
A Cornish boiler, £17.
A Lancashire boiler, £20.
If the feed-water be bad the cost will be much higher.

Chimneys :—

Let H = Height in feet.
L = Length of flue and height of chimney in feet.
V = Velocity with which the gases travel in the chimney in feet per second.
D = Inside dia., if round, or length of side, if square, in feet.
h = Head in feet of air, of the temperature of the air inside the chimney, required to produce the draught.
T = Absolute temperature of gases discharged by chimney.
t = Absolute temperature of air before entering the furnace.

Then :—

(78.) $h = \frac{V^2}{64}\left(13 + \frac{\cdot 048L}{D}\right)$

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$$(79.)\quad H = \frac{h}{\left(0{\cdot}96\,\frac{T}{t} - 1\right)}$$

In practice 300 cubic feet of air will be required per lb. of coal burned; and the absolute temperature and volume of the discharged gases will be about double the absolute temperature and volume of the air before entering the furnace. About 16 feet per second is a fair value for V.

Authorities.—"A Practical Treatise on Heat," Box; "The Mechanical Engineering of Collieries," Percy; "Pocket-Book of Engineering Formulæ," Molesworth; "Steam Boilers," Armstrong; "The Mines Act, General and Special Rules; The Steam Engine," Rankin; "The Theory of the Steam Engine," Baker; "Steam and the Steam Engine," Clark. Trans. N.E.I., xvii. and xxxii.; "Tall Chimney Construction," Bancroft; "The Workshop Companion," Templeton; "The Steam Engine," Cotterill.

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TRANSMISSION OF POWER.

It is impossible to place boilers in a mine inbye at long distances from the shaft. The economical transmission of power, therefore, to long distances is a matter of great importance.

Wooden spears may be used for distances of 300 or 400 yards, where the road is straight; but for distances greater than this our choice is confined to *compressed air*, *wire ropes*, *steam*, and, in certain cases, *water*. Some day, possibly. *electricity* may be used for this purpose.

Compressed air.

Theory.—We note in our practical experience of compressors and air engines that:—

1. If you compress air (*i.e.*, do work upon it), you will raise its temperature, and the rise in temperature will be an exact measure of the work done upon the air.
2. If you expand air against any opposing force (*i.e.*, get work out of it), you will lower its temperature, and the fall in temperature will be an exact measure of the work got out of the air.
3. If you raise the temperature of air you will increase its expansive force.
4. If you lower the temperature of air you will decrease its expansive force.

These phenomena can be easily explained if we assume the truth of the dynamical theory of gases. It is supposed that the particles of air are flying about in all directions; and that, if they were not retained by any force, they would fly apart into infinite space. The particles strike against one another, and against the sides of the vessel that contain them; and, being perfectly elastic, they rebound with a velocity equal to the velocity of collision. The energy of the particles is the heat that the air possesses. To increase

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the temperature is to increase the energy, *i.e.*, to increase the velocity of movement of the particles. To decrease the temperature is to decrease their velocity. In other words, then, "Heat is a mode of motion."

Suppose we have a cylinder full of air and the piston be pushed down. The particles of air striking the piston will rebound from it with their original velocity, plus an increased velocity due to the velocity of the piston. That is to say the advancing piston striking the particles will increase their velocity, which we have just seen is equivalent to an increase of temperature. Conversely if the piston be pushed back again by the expansive force of the air, each particle that strikes the piston gives up a portion of its energy to it, and rebounds with a decreased velocity, *i.e.*, there will be a decrease in the temperature of the air.

Changes in the temperature, pressure, and volume of air are governed by the following laws:—

Let P_1 V_1 and T_1 = the initial pressure, volume and absolute temperature of a given weight of air.

P_2, V_2, and T_2 = the final do. do.

Then—

(80.) At constant temperature $P_1V_1 = P_2V_2$.

(81.) At constant pressure $\frac{V_1}{V_2} = \frac{T_1}{T_2}$.

(82.) At constant volume $\frac{P_1}{P_2} = \frac{T_1}{T_2}$.

If air be expanded or compressed adiabatically, the following relations hold good:—

(83.) $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{1 \cdot 408}$

(84.) $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\cdot 408} = \left(\frac{P_2}{P_1}\right)^{\cdot 29}$

The units of work = U, required to compress a volume of air = V_1, to a volume of air = V_2; or to compress a volume = V_1, from P_1 to P_2.

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1st, *isothermally* : *i.e.*, at constant temperature, are :—

(85.) $U = P_1V_1 \text{ hyp log. } \frac{V_1}{V_2}$.

2nd, *adiabatically* : *i.e.*, without loss of the heat due to compression, are :—

(86.) $U = \frac{P_1V_1^{1 \cdot 408}}{\cdot 408} \left\{ \frac{1}{V_2^{\cdot 408}} - \frac{1}{V_1^{\cdot 408}} \right\}$.

As, when air is compressed adiabatically, the rise in its temperature is an exact measure of the work done upon it; the units of work required to compress it can be calculated from the rise in temperature. This increase of temperature $T_2 - T_1$ is given by (84); and the units of work = this quantity × weight of the air in lbs. × specific heat of air at constant volume expressed in foot lbs., viz. :—130·3.

Thus if W = weight of the air in lbs. :—

(87.) $U = (T_2 - T_1)\ 130 \cdot 3\ W$.

Conversely in order to calculate the units of work given out by compressed air when expanded isothermally or adiabatically the same formulæ (*i.e.*, 85 to 87) should be used.

Practice.—In order to compress air a Ram Compressor may be used if there be a plentiful fall of water ("Power of Water," Weale's series, No. 82); or the compressors of Sommeiller, Colladon, &c., described by André in his "Mining Machinery," where a fall of water is not available.

Loss due to *physical properties of air.*—Cooling of compressor with cold water, heating of air-engine with hot water or with steam; clearance spaces.

Loss due to *friction in conducting pipes.*—The formula for calculating this is of the same form for all fluids, and is given on p. 62, formulæ (97) to (99). P—p. is the loss of pressure between the compressing engine and the air engine, and *d* is the weight in oz. of a cubic foot of the compressed air, which last may be got from formula (144), bearing in mind that two inches of the barometer are equal to 1 lb. of pressure.

The greater the pressure of the air the less its efficiency.

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Mr. W. Daniell found that, with a pressure of 19 lbs. above the atmosphere, the compressed air gave 45·8 per cent. of the horse-power of the compressing steam-engine; with a pressure of 40 lbs. above the atmosphere, 25·8 per cent. only.

The following books may be consulted :—"Spon's Dict. of Eng. Supp.;" Trans. N.E.I., xxi., xxii., xxxi.; "Mining Machinery," André; "Power of Water," Glynn; "Transmission of Power by Compressed Air," Zahner.

Wire Ropes.

Wire rope, or Telodynamic, transmission, is not used in England so much as we think it might be; though the confined passages of a mine will not admit of the large sheaves necessary for a perfect installation.

HP = Horse power transmitted to driven sheave.
S = Speed of rope in feet per minute.
P = Force, or pull of rope, in lbs.
K = Coefficient of efficiency depending upon the dimensions of the sheaves, the distance, &c.

$$(88.)\quad HP = \frac{KPS}{33{,}000}.$$

Where the main and tail rope system of haulage is in use, the return sheave may be utilised for working a pump or other machinery. It should be cleaded with wood, which can be renewed from time to time. If, however, a special installation has to be made, it will be better to use an endless rope. The driving and driven sheaves should be of large diameter, 200 times that of the rope is found to be the best proportion; but little more than half this can be attained in mines. They should be cleaded with wood —willow is the best—gutta-percha, or leather set on edge. The intermediate sheaves may be a foot in diameter, though the larger they can be made the better, up to six feet; the rope of tough, flexible steel, made of a large number of small wires. With large main sheaves (12 to 15 feet), its speed should be from 30 to 40 miles an hour, and it is under these conditions, viz. :—A rope running at a great speed, under a small strain—that a rope transmission is

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most effective. With the small sheaves (say main sheaves six feet, and intermediate sheaves 12 inches), that can only be used in mines, about 12 miles an hour would be a suitable speed; and we know of one transmission, running at only 6 miles an hour, that was fairly successful. The objection to these slow speeds is the great strain upon the rope. Binding sheaves are not required; but it is convenient to have the driving or the driven sheave set upon a sliding carriage to compensate for the stretching of the rope.

The loss of power due to friction, &c., in a carefully-proportioned, above-ground transmission, appears to be only about $2\frac{1}{2}$ per cent., and $\frac{3}{4}$ per cent. in addition for each 1,000 yards. In the mine, however, such perfection cannot be attained on account of the small diameter of the sheaves and rollers, and the numerous curves. For distances of from 2,000 to 3,000 yards, 30 to 40 per cent. of the horse-power of the engine will be absorbed in driving the ropes.

Authorities:—Proc. I.M.E., 1874, p. 56; Trans. N.E.I., xvii.; "Transmission of Power by Wire Ropes," Stahl; "The Engineer," xxiii. and xxxvii.

Steam.

The losses in a steam transmission are of two kinds, viz.:—

1. Loss of steam from condensation.
2. Loss of pressure from friction.

The loss of heat, and consequent condensation, is due to two causes—radiation and contact with air.

Loss by Radiation.

Let U = units of heat lost by radiation, per hour.
S = surface of covered pipe in square feet.
D = difference of temperature in degs. Fahrenheit between surface of covered pipe and drift or shaft sides.
R = (see Table XVII.)

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Then—

(89.) $U = 0{\cdot}74DSR$.

Let L = lbs. of steam condensed per hour.

H = latent heat of steam (see Table XVI.) at the mean pressure in the pipe.

Then—

(90.) $L = \frac{U}{H}$.

TABLE XVII.

THE RATIO OF HEAT EMITTED OR ABSORBED AT DIFFERENT TEMPERATURES.

Let R = ratio of loss of heat.

t = cent. temperature drift sides.

T = cent. difference of temperature between pipe surface and drift sides.

Then—

(91.) $R = \frac{124{\cdot}72 \times 1{\cdot}0077^{t} \times (1{\cdot}0077^{T} - 1)}{T}$.

Reduced to Fahrenheit's scale this formula gives the following, Table XVII. :—

T.	*t.*							
	59°	63½°	68°	72½°	80°	86°	91°	95°
Degs.	R.	R.	R.	R.	R.	R.	R.	R.
18	1·120	1·14	1·165	1·178	1·223	1·254	1·271	1·300
27	1·14	1·159	1·185	1·190	1·247	1·276	1·305	1·327
36	1·16	1·177	1·206	1·202	1·272	1·299	1·330	1·352
45	1·18	1·20	1·229	1·231	1·297	1·323	1·357	1·381
54	1·20	1·23	1·251	1·261	1·323	1·348	1·385	1·406
63	1·225	1·25	1·276	1·289	1·350	1·375	1·407	1·435
72	1·25	1·283	1·302	1·317	1·377	1·403	1·429	1·464

Loss by Contact with Air.

This will be greater with horizontal than with vertical pipes.

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Horizontal Pipes.

Let U_1 = units of heat lost per hour by a horizontal pipe from contact with air.

S = surface of covered pipe in square feet.

R_1 = (see Table XVIII.)

D_1 = difference of temperature in degrees Fahrenheit between surface of covered pipe and the air.

A = (see Table XIX.)

Then—

(92.) $U_1 = D_1 R_1 A S$,

And the lbs. of steam condensed can be found from (90).

TABLE XVIII.

THE RATIO OF HEAT EMITTED OR ABSORBED BY CONTACT WITH AIR WITH GIVEN DIFFERENCES OF TEMPERATURE.

Let R_1 = ratio of loss of heat.

t = difference of temperature of the pipe surface and the air in degrees cent.

Then—

(93.) $R_1 = \frac{0{\cdot}552 \times t^{1{\cdot}233}}{t}$.

Reduced to Fahrenheit's scale, this formula gives the following, Table XVIII. of values of R_1:—

t.	R_1.	t.	R_1.
Degrees.		Degrees.	
9	0·782	54	1·219
18	0·943	63	1·263
27	1·037	72	1·305
36	1·109	81	1·341
45	1·168	90	1·372

TABLE XIX.

If r = radius of horizontal covered pipe in inches,

(94.) $A = 0{\cdot}421 + \frac{0{\cdot}307}{r}$.

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r	A.	r	A.	r	A.	r	A.
2	0·5745	$3\frac{1}{4}$	0·5154	$4\frac{1}{2}$	0·4892	$6\frac{1}{2}$	0·4682
$2\frac{1}{4}$	0·5574	$3\frac{1}{2}$	0·5087	$4\frac{3}{4}$	0·4856	7	0·4648
$2\frac{1}{2}$	0·5440	$3\frac{3}{4}$	0·5028	5	0·4824	$7\frac{1}{2}$	0·4619
$2\frac{3}{4}$	0·5326	4	0·4978	$5\frac{1}{2}$	0·4768	8	0·4593
3	0·5230	$4\frac{1}{4}$	0·4930	6	0·4722	9	0·4551

Vertical Pipes.

Let U_{11} = units of heat lost per hour by a vertical pipe from contact with air.

A_1 = (see Table XX.)

Then— S, R_1, and D_1, as in (92).

(95.) $U_{11} = D_1\ R_1\ A_1\ S,$

And the lbs. of steam condensed can be found from (90.)

TABLE XX.

If r = radius of vertical covered pipe in inches.

h = height of vertical pipe in inches.

Then—

(96.) $$A_1 = \left\{ \cdot726 + \frac{\cdot2163}{\sqrt{r}} \right) \times \left(2\cdot43 + \frac{5\cdot49}{\sqrt{h}} \right\} \times \cdot2044.$$

This formula gives the following Table XX., taking A_1 in feet.

Radius in Inches.	Height of Pipe in Feet.			
	50	100	200	300
r	A_1.	A_1.	A_1.	A_1.
2	0·4769	0·4650	0·4571	0·4534
$2\frac{1}{2}$	0·4676	0·4560	0·4478	0·4442
3	0·4614	0·4500	0·4419	0·4384
$3\frac{1}{2}$	0·4562	0·4448	0·4368	0·4333
4	0·4526	0·4412	0·4333	0·4299
$4\frac{1}{2}$	0·4491	0·4378	0·4300	0·4266
5	0·4462	0·4352	0·4273	0·4239
$5\frac{1}{2}$	0·4437	0·4328	0·4250	0·4216
6	0·4416	0·4298	0·4220	0·4186
$6\frac{1}{2}$	0·4398	0·4289	0·4212	0·4178
7	0·4380	0·4272	0·4196	0·4162
$7\frac{1}{2}$	0·4366	0·4257	0·4181	0·4147
8	0·4352	0·4244	0·4168	0·4134
9	0·4330	0·4220	0·4146	0·4112

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By means of the above formulæ and tables, the quantity of steam that will be condensed (that is to say, the quantity of steam that must be produced by the boiler in addition to that required to drive the engine,) in the range of pipes can be easily calculated if only the surface temperature of the pipes, of the air, and drift sides be known. How these may be obtained will be presently pointed out.

Loss by Friction.

The laws governing the resistance that fluids meet with in passing through iron pipes (and other conduits also; in which, however, we are not now interested) do not appear to be thoroughly understood. M. Stockalper, however, found, from experiments upon the flow of compressed air through pipes made at the Mont Cenis tunnel, and published in the "Revue Universelle des Mines," Sér. 2, Vol. VII., p. 257, that Darcy's formula for the flow of water through iron pipes, reduced in the ratio of the density of air to that of water, gave satisfactory results. Acting upon these suggestions, the author has made use of Darcy's formula for the flow of water, after having converted it into British units, as follows:—

Let P = boiler pressure in lbs. per square inch.
p = pressure required at engine in lbs. per square inch.
l = length of pipe in yards.
d = weight of 1 cubic foot of the fluid in oz. (for steam, see Table XVI.)
D = diameter of pipe in inches.
Q = cubic feet of the fluid passing per second. (See below.)
a = (See Table XXI.)

Then—

P $-p$ = loss of pressure between boiler and engine;

And—

$$(97.)\quad P-p=\frac{laQ^2d}{1,000,000}.$$

$$(98.)\quad Q=\sqrt[2]{\frac{1,000,000\,(P-p)}{lad}}.$$

$$(99.)\quad a=\frac{1,000,000\,(P-p)}{lQ^2d}.$$

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There is some difficulty in finding the value of this quantity Q, the mean volume; but assuming that, in a pipe of uniform section, with no very great variation in temperature, the condensation takes place uniformly from end to end; and that the loss from leakage is inappreciable :—

If V = volume of steam in cubic feet per second produced by the boiler.

v = volume of steam in cubic feet per second consumed by the engine.

Q = mean volume in cubic feet per second passing through the pipe.

Then, assuming that $V - v$ is the volume of steam lost by condensation; that is to say, neglecting leakage :—

$$(100.)\quad Q^2 = \frac{V^2 + Vv + v^2}{3},$$

and formula (97) becomes—

$$(101.)\quad P - p = \frac{l\,a\,d}{1{,}000{,}000} \times \frac{V^2 + Vv + v^2}{3}.$$

TABLE XXI.

VALUES OF a FOR DIFFERENT INTERNAL DIAMETERS D, OF PIPES IN INCHES.

$$(102.)\quad a = \frac{306{,}703{,}494\,b}{D^5};\ \text{and}$$

$$(103.)\quad b = \cdot 000507 + \frac{\cdot 00050946}{D}$$

Internal Diameter of Pipe in Inches.	a.	Internal Diameter of Pipe in Inches.	a.
1½	91,960	5½	36·54
2	7,302	6	23·29
2½	2,232	6½	15·47
3	812	7	10·58
3½	381	8	5·34
4	190	9	2·927
4½	103·7	10	1·717
5	59·7	11	0·9872

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The Design of a Steam Transmission.

The only difficulty that can arise in making use of these formulæ for the purpose of determining the size of pipes and boiler power required for any proposed transmission, lies in the estimation of the surface temperature of the covered pipe. This will depend upon the composition used, and its thickness; and upon the temperatures of the steam, the air, and drift sides. As it is independent of the diameter and length of the pipe, the simplest plan is to make an experiment by covering three or four yards of pipe with the composition to be used. Or reference may be made to a very valuable series of experiments upon various non-conducting compositions, carried out by Mr. Bird, Assoc. Sc., and read before the N. of England Institute. See Vols. XXIX., XXXI., and XXXII.

The following, Table XXII., shows the results of some experiments made by the author with Wormald's composition. It will be noted that the differences of temperature do not vary much :—

TABLE XXII.

EXPERIMENTS WITH WORMALD'S COMPOSITION.

Thickness of Composition.	Approximate Temperature of the Steam.	Temperature of Surface of Covered Pipe.	Temperature of the Air.	Difference of Columns 3 and 4.	Temperature of Drift Sides.
Inches.	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.
1⅛	281	122	77	45	72
1¼	275	101	62	39	62
1⅜	275	100	62	38	62
1 7/16	281	121	77	44	72
1 7/16	271	120	77	43	72
1 11/16	285	120	79	41	74
1¾	287	132½	91	41½	89
1⅞	287	132	94	38	93½
1⅞	287	109	77	32	open air
1⅞	286	107	76	31	do.
2⅛	287	107	77	30	do.
2⅛	286	104	76	28	do.

Having determined the temperatures in one or other of these ways, the steam required to supply the condensation

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can be readily obtained from formulæ (89) to (95). Experience seems to show that a little under 10 per cent. must be added to this for condensation at the steam traps and expansion joints.

The volume required for the engine is of course known, and this (the engine volume) added to the condensation volume gives the gross quantity to be supplied by the boiler, and consequently the boiler power required.

The mean volume squared passing through the pipe is got from the engine volume and condensation volume by formula (100), and finally the size of the pipes from formula (99) and Table XXI.

Practical Details.

Provision must be made for carrying off the water of condensation, and for expansion of the steam pipes. The first is well understood, and I would only suggest that a trap be placed as near the boiler as possible, to intercept the water carried over by priming. It was found at Broomhill that whereas the trap next the boiler gave a gallon per 7·3 yards of pipe, the second trap from the boiler gave a gallon per 15·8 yards.

For the low pressures usually adopted at collieries (say not more than 45 lbs. above the atmosphere) the ordinary stuffing-box expansion joint answers admirably; but with higher pressures there is considerable difficulty. The New York Steam Company (pressure 80 lbs.) have made a great many experiments upon expansion joints, and finally settled upon a modification of the diaphragm joint. It is made of discs of copper 0·04 inches thick, corrugated concentrically, and supported on radial backing plates, which prevent the diaphragm from being distended to rupture by the pressure.

Provision must be made for dealing with the exhaust steam. If the engine is used for pumping, and there be sufficient water, the simplest plan is to turn the exhaust direct into the suction pipe. By this means not only is the steam killed but a vacuum is obtained, and the engine made more efficient. At East Howle Colliery, instead of turning the exhaust direct into the suction, they carry the exhaust pipe some thirty yards inside the rising main, and then turn

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it into the suction pipe. By this means they consider that they get a more perfect condensation than if the exhaust steam were turned direct into the suction; and they certainly pass cold water through the pump instead of hot, which is an undoubted advantage.

Authorities:—Box on "Heat;" Trans. N.E.I., Vols. XXIX., XXXI., XXXII., XXXV., and XXXVI.

Summary.

A *compressed air* installation requires a large capital expenditure: but once established, it is not expensive to maintain where fuel is cheap. It is the most handy form of transmission for mining purposes, as the power can be readily split up by means of branch pipes, and carried in small quantities to numerous points. In addition, the exhaust air improves the ventilation, cools the mine, and can be used for clearing away gas.

A *wire rope* transmission is much less costly in the first case than compressed air; and, if properly laid out, a large quantity of power may be led to one or two points with little loss of useful effect. But the cost of maintenance is larger and the power cannot be readily carried in small quantities to many points.

Steam is not to be recommended, except in special cases; for, however carefully the pipes may be covered and the exhaust dealt with, there will always be a considerable escape of heat, which is very inconvenient in the confined passages of a mine.

Electricity is not likely, we think, ever to compete successfully with wire ropes or with air for the transmission of power in mines; where the maximum distance is only about three miles. It will, however, no doubt be applied some day for the transmission of power to very great distances. It is immaterial whether the road be straight or crooked; whether the work to be done be concentrated, or distributed in small quantities over many points.

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MAGNETISM AND ELECTRICITY.

Practical Electro-Magnetic Units.

Electromotive-force (and Potential) :—The Volt = 10^8 absolute units ; and is from 5 to 10 per cent. less than the E.M.F. of one of Daniell's cell.

Resistance :—The Ohm = 10^9 absolute units ; and is about equal in resistance to 48·5 metres of pure copper wire, 1 mm. dia., at 0° cent.

Current :—The Ampère = 10^{-1} absolute units ; and is that furnished by an E.M.F. of one volt, through a resistance of one ohm.

Quantity :—The Coulomb = 10^{-1} absolute units ; and is the quantity of electricity passing per sec. across any section of a circuit through which a current of one ampère is flowing, *i.e.*, one Ampère = one Coulomb per second.

Capacity :—The Farad = 10^{-9} absolute units ; and is the capacity of a conductor which a charge of one coulomb raises to a potential of one volt.

To calculate the Horse-power of a current :—

Let HP = Horse-power.
A = Ampères.
V = Volts.

Then :

(104.) $$HP = \frac{AV}{746}.$$

One Ampère volt = one Watt.
∴ one Horse-power = 746 Watts.

Compass Surveying.

It must be remembered that the needle does not point to true north ; but, in Great Britain, at the present time, to the west of true north : and that the angle contained by these

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two straight lines; viz., the true north and south line, and the magnetic north and south line, differs at different places. This angle, at any place, is called the declination—or, more commonly, the variation—of the needle for that place. The variation is the same along a straight line drawn through the North of England coal-field, skirting the W. side of Durham, and the E. side of Newcastle. At the present time, the magnetic variation on this line is 19° 29′ W. of N. At collieries in this coal-field E. and W. of this line, the *maximum* difference is 15′; viz., 15′ less on the E., 15′ more on the W. The variation is decreasing at the rate of about 7′ a year, so that, in 1890, the variation along the above line will be $19° \ 29' - (7' \times 3) = 19° \ 29' - 0° \ 21' = 19° \ 8'$ W. of N.

TABLE XXIII.

PLAN EQUIVALENTS.

Inches per Inch, *i.e.*, Scale.	Feet per Inch.	Yards per Inch.	Chains per Inch.	Miles per Inch.	Acres per Square Inch.	Inches per Mile.
792	66·0	22·0	1·0	0·0125	0·10	80·0
1,584	132·0	44·0	2·0	0·0250	0·40	40·0
2,376	198·0	66·0	3·0	0·0375	0·90	26·66
2,500	208·33	69·44	3·15	0·039	0·996	25·344
3,168	264·0	88·0	4·0	0·05	1·60	20·0
3,960	330·0	110·0	5·0	0·0625	2·50	16·00
7,920	660·0	220·0	10·0	0·125	10·0	8·0
10,560	890·0	296·66	13·33	0·166	17·77	6·0
63,360	5,280	1,760	80·0	1·0	640·0	1·0
126,720	10,560	3,520	160·0	2·0	2,560	0·5
190,080	16,840	5,280	240·0	3·0	5,760	0·333
253,440	21,120	7,040	320·0	4·0	10,240	0·25

Firing Shots

The advantages of Electric Shot Firing are:—Shots fired simultaneously thereby more effective. Saving of time. Safer, because not fired until all men are out of the way; and should a shot miss, it cannot fire afterwards in the face of the workman examining it.

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Two kinds of fuse are used, viz. :—

(1.) *Tension fuse* fired by a frictional, or magnetic-electric machine.

(2.) *Quantity fuse* fired by a voltaic battery.

(See "Practical Treatise on Coal Mining," by André, p. 208.)

Signalling.

The Single-wire System, in which signals can only be sent from certain fixed stations.

The Double-wire System, in which signals can be sent from any point, by making contact between the two wires.

In both these systems, the electric current is made to ring a bell; and a convenient form of battery is the Leclanché, as it does not require much attention, and is not liable to speedy exhaustion.

Lighting.

The Incandescent Lamps of Maxim, Swan, &c., are used, both for lighting at bank and below ground. These are stationary lights, and the current is produced by a dynamo-electric machine, driven by any convenient water, or steam-engine, with which dynamo the lamps are connected by means of wires. No moveable lamp has yet been used in mines, as there is a difficulty about the battery. Mr. Swan, however, is engaged upon this problem and has invented a portable miners' electric lamp; but, as at present constructed, it is too costly for practical use. One great advantage of the incandescent lamps, is that, burning only in a vacuum, they cannot (if reasonable precautions are taken to prevent breakage of wires) fire gas.

In an installation of 50 lamps and upwards, each lamp of 20 candles, one horse-power is required per 8 to 10 lamps.

Swan's 20-candle lamps, *joined in series*, require an E.M.F. of 45 to·60 volts per lamp, with a current of one ampère. *Joined parallel*, they require a current of one ampère per lamp, with an E.M.F. of from 45 to 60 volts.

Geissler Tubes, as in the lamp of Benoit and Dumas, have been suggested; but the lamp is heavy, and the light small.

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Transmission of Power.

A little has been done in France in this direction. The efficiency of electricity compared favourably with the alternative, compressed air. (See Trans. N.E.I., xxxi., Abs., pp. 9—11, xxxii. Abs., pp. 13, 14, xxxiii. Abs., p. 71, and xxxiv.)

Fire-Damp Detectors.

Liveing, Ansell, Maurice, Swan, and Somzée have each contrived an electric fire-damp detector. That of Liveing seems the most practical, and is in regular use at Pagebank and other collieries. They are all described in the Trans. N.E.I.

Danger.

From shocks, there is none when a continuous current of not more than 200 volts, or an alternating current of not more than 75 is used. This is, I believe, the limit adopted by the Board of Trade, and errs slightly on the right side.

From sparks firing gas, should any be present, must always be guarded against. This may occur at the commutator; or from a broken wire, the spark leaping across the space between the two ends at the moment of rupture.

The following books may be consulted:—"Electricity and Magnetism," Silvanus Thompson; "Electricity," John T. Sprague; Trans. N.E.I., Vols. xxx., xxxi., and xxxvi.

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SEARCH FOR MINERALS.

Mineral deposits. { Irregular.
Regular. { 1. Lying at high angles by costeaning.
2. Lying at low angles by boring.

1. *Costeaning*:—A simple process requiring no machinery.

2. *Boring*:—Theoretically, borings, of one or more holes, should give us the following information, viz.:—

One hole:—Vertical distance from the surface to the deposit; thickness of the deposit; quality of the deposit.

Three holes:—(In addition to the above) amount of dip; direction of dip.

To find the amount and direction of dip of a bed, by means of three bore-holes.

Let A, B, and C, be the three bore-holes.

S = Angle of dip of bed.
V = Angle between the strike of the bed and AB.
a = Distance from A to B.
a′ = Do. A to C.
W = Angle in a horizontal plane between AB and AC.
d = Difference of the depths of A and B.
d′ = Do. A and C.

In both cases starting from the same horizontal plane.

(105.) $$\text{Tan } S = \frac{d'}{a \sin V}.$$

(106.) $$\text{Tan } V = \frac{\dfrac{da'}{d'} \sin W}{a - \dfrac{da'}{d'} \cos W}$$

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Borings are made :—*By hand, a jet of water, Mather and Platt's process, the Diamond Process.*

Hand-boring :—The head-gear, rods (wood, iron, steel, ropes), and tools (cutting, clearing, extracting).

The Diamond Process.—The engine, quill, rods, sediment tube, core tube, crown, split-ring, and core.

Iron rods weigh about 21 lbs. per square inch of section per fathom; and 18½ lbs. per square inch of section per fathom in water.

Cost of boring.—For average coal measure rocks, 7*s.* 6*d.* per fathom for the first five fathoms; 15*s.* per fathom for the second five fathoms; 22*s.* 6*d.* per fathom for the third five fathoms and so on, has been a standard price in the north for many years. A Scotch borer in 1883 advertised his price at 4*s.*, in the place of 7*s.* 6*d.*, as above. The price for diamond boring is 6*s.* per foot for the first 100 feet; 12*s.* per foot for the second 100 feet; 18*s.* for the third, and so on.

To find the cost of a bore-hole—

Let c = cost.

a = price for first step.

d = increase in price for each additional step in depth.

n = number of steps.

$$(107.)\quad c = \left\{ 2a + (n - 1)\, d \right\} \frac{n}{2}.$$

When n is not a multiple of a, this rule is only approximately correct.

The following deep bore-holes may be mentioned :—At Schladebach, Leipzic, 956 fathoms, 11 in. dia. at the top and 1·22 in. at the bottom; it begins in the Trias, and passes through the Permian into the Devonian formation, which point was reached in the summer of 1886. Sperenberg, Berlin, 695⅓ fathoms, 12 in. dia., all in rock salt excepting the first 47⅙ fathoms. Creusot, by Kind, 503 fathoms. The Rochefort bore-hole, 469 fathoms in Triassic beds. The Mondorf bore-hole, Luxemburg, 400 fathoms. The New

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Saltzwerk bore-hole, Westphalia, 380 fathoms. And the Sub-Wealden bore-hole, near Battle in Sussex, 317½ fathoms.

The following books may be consulted :—"Mining Machinery," André; "Mine Engineering," Greenwell; Trans. N.E.I., Vols. ii., x., xiii., &c.; and "Lectures on Mining," Callon.

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Mines Act, &c.

Prohibition of single shafts, secs. 16, 17 and 18. Fencing abandoned mines, sec. 37. Fencing and securing shafts, inspection, &c. General Rules, 18 to 38.

Pits may be sunk by means of :—

(1.) Men and machinery placed at the bottom of the pit.
(2.) Men and machinery situated at bank.

(1.) Workmen in the Pit.

The ordinary method adopted in the North of England is fully detailed in the works of André and Greenwell. The workmen, standing upon the bottom of the pit, blast out the rock, and send the excavated material to the surface by means of an engine, rope, and kibble. The sides of the shaft are retained first by temporary cribs and backing deals, and afterwards by a permanent walling. The feeders of water are drawn to the surface in the kibble or pumped by a set hanging in the shaft, and are finally tubbed back, one after the other, as they are met with. This system is all that can be desired under ordinary circumstances.

Herr Poetsch's freezing method :—See "Colliery Guardian," Nov. 16th and 23rd, 1883. May be adopted where the feeders are too excessive for the ordinary method and the ground too loose for the Kind-Chaudron process.

(2.) Workmen at Bank.

The Kind-Chaudron method :—The barrack, the engine, the rocking-lever, the spears, the free-fall, the trépan, the whimble, the tubbing, the moss box, and the concrete backing. The cost is very variable, from £74 to £338 per fathom having occurred in actual practice.

Warington-Smyth sums up an account of this method as follows :—

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1. A very hazardous operation has been converted into a comparative certainty.

2. An economy of 50 to 75 per cent. has been effected on the outlay, as compared with the ordinary system carried out in the same districts. This immense gain arises mainly from :—

a. No pumps or pumping engines being required

b. The prevention, in a great degree, by the pressure of the water in the shaft, of irruptions of quicksand.

c. The employment of a comparatively small number of men, and these being, for the most part, workmen of a less highly-paid order than the regular sinkers.

d. The suppression of the vertical joints of the tubbing, whereby leakage, costs of wedging, and tendency to displacement, are avoided.

3. Risk to life is, to a great extent, eliminated by the whole of the work being done at the surface.

4. Damage to the buildings and wells of the neighbourhood is prevented by the process not requiring the drawing of water and sand. (Trans. N.E.I., xx., 198.)

The Chavette method for sinking through running sands. See Trans. N.E.I., xxxii., Abs. p. 51.

Chaudron's rule for thickness of tubbing is :—

Let E = Thickness in metres (1 m. = 39·37 inches).
R = Radius of shaft in metres.
P = Pressure in kilogrammes per square centimetre (100 metres of water weigh 10 kilogrammes per square centimetre.)

$$(108.)\quad E = \cdot 02 + \frac{RP}{500}$$

See formula (42).

Shaft Fittings.

Walling :—This is made of bricks, fire-clay lumps, stone, or concrete. For strength see formula (42).

Tubbing :—To keep back water, of cast-iron in segments or rings.

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Brattice :—Now that each colliery must have two shafts, permanent brattice is not much used. The Countess shaft, Whitehaven, is divided into four compartments by a masonry brattice; the courses are 10 inches thick and arched, so that each is self-supporting.

Guides :—These are made of wood, iron rods, iron or steel rails, or of wire ropes. Wire ropes are, perhaps, the best, on the whole, as they take up very little room in the shaft, and admit of the cage being run with great velocity.

Water rings; Keeps; Rappers :—Wire with lever, speaking-tube, or electric. *Shaft-gates;* and *water rings* are also required.

The Cost of sinking and fitting up a shaft by the ordinary method depends, to some extent, upon the diameter and depth of the shaft, the rate of wages and materials; but much more upon the strata met with and the quantity of water. Some items of the cost for a 14 feet pit, 100 fathoms deep, sunk through ordinary coal measure strata and with little water, would be about:—Total labour cost of sinking and walling £25 per fathom; Contractor for sinking, including small stores £14 per fathom. Making walling beds, £6 each; Walling with fire-clay lumps, £15 per fathom walled; Tubbing, with cast-iron segments, £90 per fathom tubbed; Plank brattice £2 10*s.* per fathom; Guides of wood, 15*s.* per fathom; Iron or steel rail guides, 50 lbs. per yard, £2 10*s.* per fathom; Wire rope guides, £1 5*s.* per fathom. And the total cost for the finished pit about £50 per fathom.

If there is a good deal of water (but still not more than can be easily mastered by the ordinary method of sinking) this price might be doubled.

Shaft Pillars, &c.

If D = Depth of shaft in fathoms.
S = Size of shaft pillars in yards.

(109.) $S = \sqrt{\frac{D}{50}} \times 22$ is an approximate rule. The exact size must depend upon the special circumstances of each case.

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UNIVERSITY CALIFORNIA

If W = Width of shaft in feet.
H = Height of hanging on place in feet.
L = Length in feet of longest prop, rail, &c., that can be taken down into the mine.

(110.) $L = (W^2 + H^2)^{\frac{1}{2}} \quad \therefore H = (L^2 - W^2)^{\frac{1}{2}}$

Some Deep Mines.

The deepest shaft in the world is I believe, that of a lead mine, the Adalbert shaft, Prizbram, 572 fathoms, 1884 (the Maria shaft, Prizbram is also about the same depth); and the deepest mine, the Viviers Reunis coal mine, at Gilly, near Charleroi, 581·5 fathoms; the depth of the shaft is 570 fathoms, but there is a staple at the bottom, 11½ fathoms deep.

The deepest mine in England is the Ashton Moss colliery, near Manchester, sunk to the Black mine, 472·5 fathoms (the total depth of the shaft is 475 fathoms). The seams dip 9″ per yard, so that parts of the workings are about 500 fathoms (1886). There are also Rosebridge colliery, Wigan, sunk to the Arley mine, 403 fathoms (the total depth of the shaft is 407½ fathoms); Dolcoath tin mine, Cornwall, 404 fathoms (1884); Harris Navigation colliery, S. Wales, 373½ fathoms to the 9-feet seam (total depth of shaft, 380 fathoms); and Dukinfield colliery, Manchester, sunk to the Black mine, 358½ fathoms.

The deepest mines in the North of England are Seaham colliery, 301 fathoms to the Busty seam; Silksworth colliery, 290 fathoms to the Hutton seam; and Monkwearmouth colliery, 287½ fathoms to Hutton seam.

Underground Temperature.

The temperature of the earth increases as we descend; but at what rate is not exactly known. In round numbers, the temperature at 100 feet is constant, and is equal to the mean annual temperature of the place. Below this point, the temperature increases 1° Fahr. for each 56 feet. The mean annual temperature of Newcastle is 49° Fahr. The temperature in the deeper parts of the workings at Ashton Moss is from 86° to 90°.

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In some of the Comstock lode silver mines, Nevada, workings are being carried on at a depth of 336 fathoms (1877), and at a temperature up to 123°, the rock having a pretty uniform temperature of 130°. This great heat is due to the hot springs, some of which have a temperature of 158° Fahr. Chemical decomposition is thought to be, in part, at any rate, the cause of this high temperature.

Important Adits.

Gwennap, Cornwall, drains 30 square miles, is 40 miles long, including branches, and varies in depth from 30 to 90 fathoms. Ernst August, Harz, 14 miles long, including branches; greatest depth, 222 fathoms, gradient 1 in 2,000. The Blackett level, from Allendale town to the mines at Allenheads, 7 miles, of which $4\frac{5}{8}$ are completed; gradient 1 in 660.

The following books may be consulted:—"Mine Engineering," by Greenwell; "Practical Treatise on Coal Mining," by André; Trans. N.E.I., xx., xxxi.; "Lectures on Mining," by Callon; "Mines, Miners, and Mining Indus., U.S.," by Drinker; "American Jour., Sci. and Arts," 3 ser., xvii.; "Mec. Eng. of Collieries," by Percy; Report of Coal Com., 1871; Proc. I.C.E., vols. lxiv., lxxi.; and "Underground Temperatures," by Prestwich.

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SYSTEM OF WORKING.

The method to be adopted depends upon a great variety of circumstances, such as the mineral worked, its mode of occurrence, &c., &c.

Minerals are found as Seams or Lodes (regular deposits). As Impregnations or Masses (irregular deposits).

Deposits vary much in thickness; confining ourselves only to those that are being, or have been worked, we find:—

Coal:—The Chapelet seam at the Hasard colliery, Liège, 1½ feet; the Three-quarter, Midgeholme, Northumberland, from 22 to 30 inches; the Maudlin, Ryhope, Durham, 12 feet; the Ten-yard seam, Dudley, upwards of 30 feet in places; the great seam, Béraudière, St. Etienne, up to 82 feet; the great seam at Bézenet up to 200 feet.

Salt:—Cheshire, 75 to 100 feet; Wieliczka, in Galicia, 100 feet; Middlesborough, up to 90 feet; Sperenberg, Berlin, 3,890 feet.

Iron-ore:—Lord Leconsfield's mine, Cleator-moor, Cumberland, 60 feet; the Lias band, Eston, 18 feet.

Silver lodes of Schemnitz, Hungary, 30 feet.

Alum Shales on the Meuse, 90 feet.

Slate Mines in the Ardennes, 60 feet.

Various as are the conditions of occurrence of mineral deposits, the systems of working them may be all classed under one or other of five heads, viz.:—

Above Ground:—

Pumping (Salt, Middlesborough).
Washing (Gold, California).
Quarrying.

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Under Ground:—

Bord and Pillar.
Long Wall.

We are not interested here in the first three.

Bord and Pillar may be defined as any system of mining in which the deposit is removed in two or more workings. A portion of the deposit being left during the first working or workings in order to support the roof and sides of the excavation. (Post and Stall, Stoop and Room, Pillar and Breast are synonymous with Bord and Pillar.)

Long Wall may be defined as any system of mining in which the whole of the deposit (or, in the case of very thick deposits, a horizontal slice of it) is removed in one working; no portion being left to support the roof and sides of the excavation.

The Long Wall and Bord and Pillar methods, as adopted in the North of England for the working of seams of coal, may be shortly described and compared as follows:—

Long Wall and Bord and Pillar.

In Long Wall, a face of considerable width, say 100 to 500 yards, is opened out, and the coal is worked along the whole distance either in one lift or in steps. The roads—main-gates and cross-gates, as they are called—pass through the goaf and are supported on packs built up of the stone taken down to form height in the roads. The roof along the face is also supported on packs made from the refuse—*i.e.*, the band or folling—of the seam, and where this fails, on timber which is drawn and shifted forwards as the face advances. All superfluous stone, &c., not required for the packs, is cast back into the goaf, and one of the main elements of success in this system of working is that there should be sufficient of this to fill, more or less completely, the void left by the abstraction of the seam, so as to let down the roof evenly and gradually.

In Bord and Pillar the seam is first cut up into rectangular masses by two sets of excavations, driven at right angles to one another, and then these masses are removed in slices

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about four to seven yards wide. The first operation is called working in the "Whole Mine," and the second working in the "Broken."

Long Wall then may be defined as any system of working in which the seam is removed at one operation: Bord and Pillar as any system in which the seam is removed by two or more series of workings.

The Bord and Pillar and Long Wall systems of working are adapted to different circumstances, so that an exact comparison is impossible, though a general one may be made as follows:—

1. *Ventilation.*—In Long Wall the air enters by the main gate, and dividing into two splits, passes along the face, returning by roads on the extreme right and left. Nothing can be simpler than this arrangement; very little brattice is required, and the air, having the shortest possible distance to travel, acquires the least possible heat from the strata, a matter of great importance in deep mines, and also requires the least possible ventilating pressure (*i.e.*, less expenditure of money) to set it in motion.

In Bord and Pillar the air also enters by the central drift or Mother-gate bord, and divides into two splits; but, as the air has to be taken into each bord, it has a very much longer distance to travel, and a great deal of brattice is required.

On the other hand, should there be much gas, it can be isolated to the bord in which it is being given off in Bord and Pillar; whilst in Long Wall it will foul the whole face on the inbye side.

2. *Produce.*—In Long Wall all the seam may be extracted, and whilst the weight of the roof helps to break down the coal at the face, it does not rest upon it long enough to crush the coal. This, combined with the small amount (if any at all) of nicking and narrow work, tends to the production of the maximum of round coal.

In Bord and Pillar all the seam cannot be extracted, as some coal must always be left in stooks, and in addition, a portion of the pillars is often lost by falls of roof. In the whole workings, small is produced by nicking and narrow work and often in the broken by crush. The result being

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a smaller production both of unscreened and of round coal than in the Long Wall method of working.

3. *Cost.*—In Long Wall the cost of putting, supervision, and materials (*i.e.*, rails, sleepers, and brattice) will be less than in Bord and Pillar because the distance is shorter; and, as there is no yard work, and the weight of the roof helps to bring down the coal, the cost of hewing also will be less. On the other hand, shift and stone work will be very expensive; so much so, that where powder cannot be used, Long Wall is, in many cases, inadmissible.

A given length of face will stow more men in Long Wall than in Bord and Pillar.

4. *Surface Damage.*—When it is intended to work out the whole of the seam less damage is done by Long Wall than by Bord and Pillar, because the space formerly occupied by the seam is filled up by the stowage, and though this cannot be done so completely as to support the weight of the superincumbent strata without considerable compression of the stowage, yet the character of the support is the same over the whole area, and the surface is let down gradually and uniformly.

In Bord and Pillar the surface damage usually takes the form of irregular depressions dotted about here and there, putting a stop to all farm drainage.

5. *Accidents.*—Accidents from falls of stone are less likely to happen in Long Wall than in the broken workings of Bord and Pillar; and, as no coal is left below ground, under ground fires, from the spontaneous combustion of small coal crushed and ground together by falls of roof, are impossible. On the other hand, gas cannot be isolated to the place where it is being given off, as in Bord and Pillar. And in Long Wall, the men being closer together, should an explosion occur, more are likely to be killed.

Summary.—Long Wall is suitable for thin seams (less than four feet) or very thick (more than twelve feet) seams, lying at any angle; especially when they produce sufficient refuse for stowage and contain no gas and few troubles.

Bord and Pillar is suitable for seams of moderate thickness (from 3½ to 8 feet) lying at low angles: especially if there be gas and troubles.

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Stoping.

In the mining of metalliferous veins a Bord and Pillar system is adopted which is called *stoping*. It may be shortly described as follows:—

The vein having been cut up by means of levels and winzes into pillars, 25 to 50 yards in length by 15 to 30 yards in height, is worked by one or other of two methods, viz.:—

1. By overhand stoping.
2. By underhand stoping.

1. *Overhand stoping.*—A jud is worked off (the full width of the vein and by 5—6 feet in height) starting from one of the lower corners of a pillar and carried right across the pillar horizontally from winze to winze. This jud, having gone 4 or 5 yards, is followed by another jud immediately above it; this is followed by a third, and so on. So that the portion of a pillar, still unworked, looks like a staircase, beneath which the miners stand; and the portion worked, which is stowed up with the deads, looks like a staircase upon which (or sometimes upon timbering) the miners stand. The useful mineral is separated from the deads and passed down from step to step, until it reaches the rolley-way below. Or else passages are left for it in the stowage down to the rolley-way level, with a sliding shutter in their lower ends by means of which the tubs are filled.

2. *Underhand stoping.*—A jud is worked off, beginning at the upper corner of a pillar, and carried right across horizontally from winze to winze. When this jud has gone a few yards, a second is set away immediately below it, and so on, so that the unworked portion of the pillar is like a staircase, upon the steps of which the workmen stand. The useful mineral is separated from the deads and passes down the staircase from step to step, until it reaches the rolley-way level. The deads are stowed away on timber above the miners' heads.

Comparison of the two methods.—The ore is broken down more cheaply by overhand than by underhand stoping; the leading of the useful mineral down the spouts is cheaper than passing it down the steps; and the stowage of the deads is more easily accomplished. The consumption of

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timber depends, perhaps, more upon the circumstances of the lode than upon the system adopted; but, as a rule, less will be required for overhand than for underhand stoping. The roof of unworked ore in overhand stoping, except when it is of a very friable nature, will be safer than the stowage roof in underhand stoping.

On the other hand, if the mineral be of a very valuable character portions of it may be lost in the stowage on its passage down the spouts or down the steps of stowage.

Shortly.—Overhand stoping is the most generally applicable. Underhand stoping—more costly from the expense of timbering, the greater difficulty of breaking the ore, of stowing the goaf, and leading away the useful mineral—is suited for those mines where the great value of the mineral makes the loss of a small quantity a matter of great importance, and for those where the ore is so friable as to make a dangerous roof for the working places. It is adopted in some German, a few English, and many South American mines.

Cost of Working.

This is very variable, depending upon the price of labour and the nature of the deposit.

In the case of coal, about one half of the labour cost is due to hewing, one-third to other underground labour, and the remaining one-sixth to surface labour. To this must be added materials, rents, rates, fuel, agency, depreciation, and interest on capital. In all, perhaps, about 5*s.* per ton on unscreened coal into waggons at the pit, in ordinary conditions of trade.

Collins in his book, referred to below, gives some costs of labour in metal mines.

The following books may be consulted:—"Metal Mining," Collins; "Metalliferous Minerals and Mining," Davies; "Ore Deposits," J. A. Phillips; Trans. N.E.I., vi. and vii.; and the books on Mining already mentioned.

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WINDING.

Winding Engines.

The work to be done is not continuous for more than a few seconds, and is variable in amount, being greatest at the lift when the whole weight of the rope and the inertia of the mass set in motion have to be overcome. The weight of the rope is counterbalanced, as see below. The resistance due to the inertia of the load may be found by the following rule:—

Let R = Resistance in lbs.
W = Weight of load in lbs.
V = Maximum velocity in feet per second
g = Force of gravity = 32.
T = Time in seconds taken to acquire the velocity V.

(111.) $R = \frac{WV}{gT}$ (See "Practical Mechanics," by Twisden, p. 231.)

The friction of the guides has to be overcome.

In designing a Winding engine to do any given work, consult the "Mechanical Engineering of Collieries," by Percy.

Counterbalances.—The common form in the north is the chain and staple. See the description of the Silksworth counterbalance. Trans. N.E.I., xxv. 201.

The Incline Counterbalance was adopted at Killingworth Colliery.

F = Counterbalancing force in lbs. for a short distance on any portion of the incline.
W = Weight of counterbalance in lbs.
H = Height of the portion of the incline in feet.
L = Length do. do.

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(112.) $F = \frac{WH}{L} \therefore H = \frac{F L}{W}$

The Pendulum Counterbalance is used at Dudley Colliery.

F = Conterbalancing force in lbs. in any position of the pendulum.
W = Weight in lbs. of the counterbalance.
A = Angle the pendulum makes with the horizontal.

(113.) $F \doteq \frac{W \cos. A}{\cos \frac{A}{2}}$

The Tail Rope Counterbalance as used at Garswood Colliery, near Wigan, consists of a rope of the same size as the winding rope. It passes round a pulley at the bottom of the shaft, and has one end fastened to the bottom of one cage, the other end to the bottom of the other cage.

The Koepe system does away with the winding drum altogether, and substitutes a sheave connected with the engine at bank. There is a return sheave at the bottom of the shaft. Two ropes are used, one connected with the tops of the cages and passing round the sheave at bank; the other connected with the bottoms of the cages, and passing round the sheave in the sump.

The Conical Drum, as used at Boldon—the full cage at the bottom of the shaft being attached to the small diameter of the cone, the empty cage at the top of the shaft being attached to the large diameter of the cone.

Automatic Variable Expansion is sometimes employed.

Drums.—Cylindrical, vertical (flat rope), or conical.

Pulley-Frames.

The principal strains are in two directions, viz., one vertical, due to the weight of the load; the other more or less horizontal, due to the pull of the engine. Timber, iron, and masonry will bear a crushing strain better than a tensile strain, or breaking across. In constructing pulley frames, therefore, the materials should be so placed as to be subjected to a crushing strain. This may be done in more

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than one way; but, in practice, it is found most convenient to employ two main struts, one vertical, parallel with the vertical portion of the rope; the other, more or less horizontal, parallel with the horizontal part of the rope.

In order to fix the size of long timber struts, see formula (41).

Pulleys.

The following rule is given for the diameter of round iron or steel rope pulleys, viz. :—

Rope,	1 in.	cir.,	requires pulley	10 ft.	diameter.
„	$1\frac{1}{4}$ in.	„	„	$10\frac{1}{2}$ ft.	„
„	$1\frac{1}{2}$ in.	„	„	11 ft.	„
„	$1\frac{3}{4}$ in.	„	„	$11\frac{1}{2}$ ft.	„

and so on.

In order to save the ropes, the pulleys are sometimes set on springs, as at Cambois Colliery.

Let F = Force in lbs. applied at rim of pulley required to overcome friction of axle.
W = Weight upon pulley axle in lbs.
D = Dia. of pulley in inches.
d = Dia. of axle in inches.
m = Coef. of friction (say 0·07).

(114.) $$F = \frac{Wmd}{D}.$$

Ropes, Chains, Cages.

Ropes are either round, flat, or tapering, and are made of hemp, aloes, iron, or steel. For deep pits, round, steel ropes, are most in favour.

For the strength of pit ropes, see formulæ (1 to 21).

Chains should be annealed occasionally, otherwise they become brittle, and are likely to snap. The general rule in the north is to anneal cage chains once a month; annealing too often, decreases their tensile strength.

For strength of chains see formula (22).

Cages are made of iron or steel, have from one to four decks, and carry from one to eight tubs. An iron cage

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weighs about $\frac{2}{3}$ of its load of full tubs; a steel cage about $\frac{1}{2}$ of its load.

Sundries.

Detaching hooks.—See Trans. N.E.I., xxix., 201.

Safety cages are not much used in the north.

To find meetings, &c., with flat ropes.

Let n = Half the number of revolutions.
d = Distance of meetings from bottom of pit in inches.
r = Radius of drum at lift in inches + $\frac{1}{2}$ t.
t = Thickness of rope in inches.

(115.) $d = 3{\cdot}1416n\,(2r + \overline{n-1}t).$

Let D = Depth of pit in inches.
n = Number of revolutions.
r = Radius of drum at lift in inches + $\frac{1}{2}$ t.
t = Thickness of rope in inches.

$D = 3{\cdot}1416n\,(2r + \overline{n-1}t.)$

(116.) $$n = \sqrt{\left(\frac{r}{t} - \frac{1}{2}\right)^2 + \frac{D}{3{\cdot}1416t}} - \left(\frac{r}{t} - \frac{1}{2}\right)$$

(117.) $$r = \frac{D - \{n\,(n-1)\,3{\cdot}1416\,t\}}{2 \times 3{\cdot}1416n}.$$

The following books may be consulted:—André, Greenwell, and Percy, already mentioned; Trans., N.E.I., xxv.

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DRAINING.

Pumps, &c.

The Lifting Pump has the engine situated at bank. Advantages and disadvantages of, viz. :—The engine is easily got at for repairs, engine cannot be drowned up, pumps can be carried down to a great depth, working parts even when drowned easily brought to bank for repairs. On the other hand: First cost very large, working cost large, take up much room in shaft.

The Forcing Pump may have its engine either at bank or in the mine. Advantages and disadvantages of, viz. :— First, when engine at bank: The engine is easily got at for repairs, engine cannot be drowned, pumps can be carried down to a great depth, the spears balance the column of water. On the other hand: First cost very large, working cost large, take up much room in shaft when more than one rising main required, and, if the working parts are drowned, they cannot be brought to bank for repairs. Second, when engine in pit: First cost is small, working cost small, take up little room in shaft. On the other hand: Danger of engine being drowned, engine not so easily got at for repairs, difficult to make joints in the rising main, and to make clacks to stand the pressure at a great depth.

The Syphon is used for bringing water over a ridge from a higher to a lower level. The short leg *must* not have a vertical length of more than 34 feet, *i.e.*, the ridge over which the water is to be lifted must not be more than 34 feet. (The greatest height of ridge in practice depends upon the special circumstances of each case.) The long leg *need* not have a vertical length of more than 34 feet. The effective pressure, expressed in feet of water column, is equal to the vertical length of the long leg in feet (not more than 34 feet), less the vertical length of the short leg in feet.

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The Shaft.

1st. *The water tub* can be used where the quantity is small; but, in some cases, large quantities have been raised in this way.

2nd. *The Winding engine pump* is a pump attached to the winding engine, usually at night; but, sometimes, whilst coal is being drawn.

3rd. *The Lifting engine* is situated at bank, and may be either a Beam engine, or Rotative engine.

4th. *The Forcing engine* may be situated at bank and may be a Cornish engine, a Bull engine, a Rotative engine; or it may be situated in the mine, and be Direct-acting or Rotative.

The Workings.

1st. *Occurrence of feeders.*—The coal-field is basin-shaped, and formed of alternate layers of permeable and impermeable strata. Water, entering at the outcrop, will run through the first until intercepted by faults, fissures, pumping shafts, &c. In the North of England Coal-field shallow pits wet; deep pits dry.

When sinking, therefore, the feeders should be tubbed back in succession, as soon as they are encountered.

2nd. *Water levels and under level drifts.*—This is the best way of dealing with water, when possible.

3rd. *Raising water from the dip* by means of—The water-tub, the hand-pump, or horse-pump, when the units of work are not very great. The tail-rope pump, steam-engine, and spears, steam-engine and rope, compressed air, and electricity, when the units of work are large. Syphons, hydraulic engines and water-wheels, may be used in some special cases.

In dealing with constant feeders by men or horses: find the units of power by multiplying the lbs. of water per minute by the vertical distance in feet and add 50°/ₒ for friction. Then :—

1 man will be required per		900	units of power.
1 horse	,,	6,000	,,

The man (or horse) will not of course work continuously

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for 24 hours per day; but if he works, say for 8 hours, *i.e.*, $\frac{1}{3}$ of a day, he will do $900 \times 3 = 2{,}700$ units of work per minute, which is equivalent to $\frac{2{,}700}{3} = 900$ units per minute of continuous work; and as the feeder is continuous, this is the most convenient way of making the calculation.

Sundries.

Acid water corrodes pumps, and its effects are enhanced by pressure. At Killingworth, the acid water was neutralised by a mixture of water and lime from magnesian limestone.

$$\text{Sulphuric Acid} + \text{Magnesian Limestone} = \text{Sulphate of Lime and Magnesia} + \text{Carbonic Acid} + \text{Water.}$$

$$(118.)\quad H_2SO_4 + (MgCa)CO_3 = (MgCa)SO_4 + CO_2 + H_2O.$$

Red water pollutes streams. It may generally be cleared by heating. At Backworth, the red water was passed through the condenser.

$$\text{Soluble Hydrogen Carbonate of Iron} = \text{Insoluble Carbonate of Iron} + \text{Carbonic Acid} + \text{Water.}$$

$$(119.)\quad FeH_2(CO_3)_2 = FeCO_3 + CO_2 + H_2O.$$

The Air Vessel is used to equalise the pressure, and so prevent shocks. As air, in contact with water, especially when under pressure, is absorbed by the water, it is necessary to supply the air vessel with fresh air. One of the most effective methods of doing this is to pump air in by means of an air-pump. See Trans. N.E.I., xxi.

Joints and Valves of special construction are required, to stand high pressures of water.

If D = Diameter of pump in inches.
G = Gallons per three-feet stroke.

$$(120.)\quad G = \frac{D^2}{10} \cdot (+2\%) \quad \therefore D = \sqrt{10G}.$$

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If D = Diameter of pump in inches.
L = Length of strokes in feet.
N = Number of strokes per minute.
G = Gallons delivered per minute.

(121.) $G = \cdot 034LND^2 \therefore D = \sqrt{\frac{G}{\cdot 034LN}}$

A pump delivers from 5 to 20% less than the actual amount due to diameter and length of stroke.

Davey gives the following rule for speed of his differential pump.

If L = Length of stroke of pump in feet.
S = Speed of pump piston, or ram, in feet per minute.

(122.) $S = \sqrt{L} \times 60.$

The speed of water in pipes should not exceed 200 to 250 feet per minute.

A convenient method of measuring feeders regularly is by means of a clay dam built across the drift. A thin iron plate is substituted for the top plank and in it a rectangular notch is cut through which the water flows.

If G = Gallons per minute.
d = Depth in inches of the sill of the notch below the surface of the water.
l = Length of notch in inches.

(123.) $G = 2 \cdot 67ld\sqrt{d}.$

The depth d must be measured in still water, *i.e.*, two or three feet away from the notch.

If F = Depth of shaft in fathoms.
P = Pressure of water in lbs. per square inch.

(124.) $P = 2 \cdot 6F.(-0 \cdot 8\%).$

If H = Head of water in feet required to overcome resistance.
G = Gallons per minute.
L = Length of pipe in yards.
D = Diameter of pipe in inches.

(125.) $H = \frac{G^2L}{(3D)^5}$

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For strength of pipes, see formula (23).

A pint of pure water weighs a pound and a quarter.

1 gallon = 277·25 cub. in. = 0·16 cub. ft. = 10 lbs.

400 gallons = 64 cub. ft., 1 cub. in. = 0·036 lbs., 1 cub. yard = 168·75 gallons.

1 cub. ft. = 6·25 gallons = 62·5 lbs. = 1,000 oz.

1 cub. fm. = 6 tons, 1 ton = 35·84 cub. ft.

The general cost of pumping from the mines of Northumberland and Durham, exclusive of interest and redemption of capital, is about one farthing per ton of water lifted 100 fathoms (Trans. N.E.I., xii., p. 181).

Boring against Old Workings.

Read the *Mines' Act General Rules, No.* 13.

The object of boring is to interpose a shell of solid coal between the exploring drifts and the old workings, which will act as a protection against water or gas.

Thickness of shell required depends upon the head of water in the old workings, the character of the seam, and the width of the drifts; but, from the want of experimental data upon the strength of coal, no very definite answer can be given to this question. In order to insure the thickness required a plan should be made, and the bore-holes set away accordingly.

Precautions to be adopted.—Bore-holes can be depended upon if made by a machine, for a distance not exceeding 30 feet. The Master Shifter should see that the holes are put up to their full distance each night, and the foreshift Deputy should measure them before permitting the hewers to begin work. The Overman and Back-Overman should see each day that the holes are being driven in accordance with the plan drawn up by the Certificated Manager. A mall and plugs should be kept ready in the face of the drift. Spare lamps should be placed a few yards outbye. When the head of water is very great, a tap, large enough to take the rods, may be wedged into the hole.

G = Gallons per hour.
L = Length of bore-hole in yards.
H = Head of water in feet.
D = Diameter of bore-hole in inches.

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(126.) $G = \frac{\sqrt{(15D)^5 H}}{L.}$

In calculating the time required to empty old workings (or any other reservoir) the fact that the value of H decreases must not be lost sight of. If the reservoir be parallel sided, assume H to remain unaltered and multiply the time thus obtained by 2. But if the reservoir be of irregular shape, divide it into thin horizontal laminæ and calculate the time required for the discharge of each separately.

Dams.

The object of a dam is to shut back water or gas.

Dams may be classed as—

1st. *Straight*, made of clay, brick, or wood.
2nd. *Wedge-shaped*, of wood.
3rd. *Cylindrical*, of brick or wood.
4th. *Spherical*, of brick or wood.

Straight brick dams are the commonest form in the north; but a spherical wooden dam is the strongest. Brick is liable to be cracked by a movement of the strata; and some Engineers advise that an india-rubber sheet should be placed upon it, next to the water.

For the strength of cylindrical and spherical dams, see formulæ (42) and (43).

Precautions to be adopted.—The spot chosen should be free from fissures, and not near any dislocation. The sides of the drift should be carefully hand-dressed. A pipe should be carried through the dam, near the top, to permit the air to escape.

Tubbing.

Tubbing may be segmental or cylindrical. For the fixing of tubbing, see either André or Greenwell.

For the strength of tubbing, see formulæ (42) to (44), and the following books may be consulted :—"Mine Engineering," Greenwell; "Practical Treatise on Coal Mining," André; Trans. N.E.I., xii., xv., xxi., xxiii., &c.

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Resistances to be Overcome.

1st. *Friction* varies directly as the weight of the tub and the diameter of the axle; and inversely as the diameter of the wheel. It is but little affected by velocity (*i.e.*, the low velocity of mine haulage), but depends very much upon the state of the road (see Trans. N.E.I., vol. xxxii.). With ordinary wheels and axles it is about 50 lbs. per ton on a good macadamised road, 10 lbs. per ton on a railway, and 24 lbs. per ton on an underground rolleyway.

If F = Resistance in lbs. due to friction upon a level rolleyway, in fair condition.
W = Weight of tub in lbs.
D = Diameter of wheel in inches.
d = „ of axle „

$$m = \text{Coefficient of friction} = 0{\cdot}0882\frac{d}{D}$$

$$= \left(\sin a - \frac{2L}{gT^2}\right)\cos a \text{ in } (128).$$

(127.) $F = mW$.

In order to find by experiment the resistance of friction upon a level road, an incline must be chosen with as regular a gradient as possible, and the time a tub takes to descend under the influence of gravity accurately measured.

Then if L = Length of incline in feet.
H = Height of incline in feet.
T = Time of descent in seconds.
W = Weight of tub in lbs.
R = Friction in lbs.
a = angle of inclination of incline.
g = gravity, say 32.

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$$(128.)\quad R = W\left(\sin a - \frac{2L}{gT^2}\right)\cos a.$$

Roughly, the gradient being moderate.

$$(129.)\quad R = W\left(\frac{H}{L} - \frac{L}{16T^2}\right)$$

2nd. *Inclination of road* will retard the set going up-hill and assist it going down.

If I = Resistance in lbs. due to inclination.
W = Weight of tub in lbs.
L = Length of incline in feet.
H = Height of incline in feet.

$$(130.)\quad I = \frac{WH}{L}$$

It follows, then, that—neglecting the fact that the resistance due to friction is rather less on an incline than on a level—if

R = Resistance in lbs. due to friction and inclination.

$$(131.)\quad R = mW + \frac{WH}{L}\text{(going up-hill).}$$

$$(132.)\quad R = mW - \frac{WH}{L}\text{(going down-hill).}$$

In order to find the gradient rising inbye, at which the resistance of the full set coming out is equal to the resistance of the empty set going in,

Let W = Weight of full set in cwts.
w = " empty set "
m = Coefficient of friction.
G = Rate of gradient $= \frac{L}{H}$.

$$(133.)\quad G = \frac{W + w}{m(W - w)}$$

3rd. *Curves.*—A greater resistance is met with in going round curves than on a straight road. The wheels, being

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fast upon their axles, must slide upon the rails, and the flanges of the wheels grind against the rails. Molesworth, page 160, gives the following formula:—

W = Weight of vehicle in cwts.
R = Resistance due to curve in cwts.
r = Mean radius of curve in feet.
D = Gauge of way in feet.
L = Wheel base in feet.
F = Coefficient of friction of wheels on rail = 0·1 to 0·27.

$$(134.)\quad R = \frac{WF(D+L)}{2r}$$

This formula (134) is intended for railway carriages, trucks, &c.; with the higher coefficient of friction (0·27), however, it appears to be applicable to mine tubs.

In order to resist the tendency to fly off the way at a curve the outer rail should be raised. This, however, is not necessary with main and tail rope haulage.

E = Elevation of outer rail in inches.
V = Velocity in feet per second.
D and r = as above.

$$(135.)\quad E = \frac{3DV^2}{8r}.$$

4th. Influence of *fast* or *loose* wheels; *conical* or *flat* treads; *parallel* or *radial* axles.

Motors.

1st. *Men.*—Seven men are considered to be equal to one horse, and one man's wage in the North of England, including house and fire-coal, is about the same as the cost of a horse.

2nd. *Horses.*—The units of work that an average horse can do, during a ten hours' shift, depend upon the speed at which he is driven, and the state of the ventilation. He is most efficient at a low speed, two or three miles an hour, and in a well ventilated mine. In these circumstances he will do about 22,000 foot-lbs. per minute ($\frac{2}{3}$ of a mechanical horse, see table XIV., p. 38), which is equal to a tractive force of 125 lbs. exerted through a distance of 20 miles in 10 hours. In practice, the velocity will be greater and the distance less.

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3rd. *Self-acting inclines.*—The weight of the full set has to overcome the friction of the full set, the empty set, the sheave or rope-roll, and rollers + the weight of the empty set and rope. This last (the weight of the rope) is a variable quantity, and is greatest at the start.

Let L = Length of incline in feet.
H = Height of incline in feet.
a = angle of incline.
F = Weight of full set in lbs.
E = Weight of empty set in lbs.
T = Time running in seconds.
g = gravity = 32.
R = Weight of rope in lbs.
S = Weight of rollers and sheave in lbs.
m = Coefficient of friction of tubs on level road.
m′ = Coefficient of friction of rollers and sheave = about 0·03 on an average.
W = Weight in lbs. of the whole mass in motion.
P = Force in lbs. moving the sets.

$$P = F \sin a - \left\{ mF \cos a + mE \cos a + m'S + E \sin a + R \sin a \right\}$$

$$= F \sin a - \left\{ m \cos a\,(F + E) + m'S + \sin a\,(E + R) \right\}$$

But $\sin a = \frac{H}{L}$ and cos a practically = 1. Therefore—

$$(136.)\quad P = \frac{FH}{L} - \left\{ m\,(F + E) + m'S + \frac{H}{L}(E + R) \right\}.$$

$$(137.)\quad T = \sqrt{\frac{2LW}{g\left\{ \frac{FH}{L} - m\,(F + E) + m'S + \frac{H}{L}(E + R) \right\}}}$$

$$(138.)\quad \frac{H}{L} = \frac{m\,(F + E) + m'S + \frac{W2L}{gT^2}}{F - (E + R)}.$$

Self-acting inclines are suitable for straight roads rising inbye one inch to the yard and upwards.

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4th. *The main and tail-rope* system is suited for a narrow plane, having a regular gradient, and several branches.

5th. *Endless chain or rope* is suited for wide straight undulating planes, without any branches. The gradient, &c., may be calculated from formulæ (136) to (138).

6th. *The main rope* system is used on planes dipping inbye one inch to the yard and upwards. The weight of the empty set has to overcome the friction of the empty set, the rollers, sheave, and rope.

$$P = E \sin a - (m \cos a \, E + m'S + m'R),$$

and we get

$$(139.)\quad P = \frac{EH}{L} - \left\{ mE + m'S + m'R \right\}$$

$$(140.)\quad T = \sqrt{\frac{2LW}{g\left\{\frac{EH}{L} - (mE + m'S + m'R)\right\}}}$$

$$(141.)\quad \frac{H}{L} = \frac{mE + m'S + m'R + \frac{W2L}{gT^2}.}{E}.$$

7th. *Compressed air-engines,* stationary and locomotive. *Hydraulic engines* and *electric motors* are also used.

A tub will hold about 50 lbs. of unscreened coal per cubic foot. The exact quantity depends of course upon the specific gravity of the coal; but also upon the size of tub and the proportion of round coal, the larger the tub and the greater the percentage of round the greater the weight per cubic foot that it will hold.

The cost of haulage is very variable, depending upon the gradients, the length of road, and quantity led. Excluding interest on capital, the cost per ton of coal conveyed one mile is about:—

$\frac{1}{2}$*d.*, ordinary railroad with locomotives.

6*d.*, ordinary road with horses, excluding maintenance of road.

$\frac{1}{4}$*d.* (?), canal with horses, excluding maintenance of canal. Canal with steam-tugs in some cases as low as $\frac{1}{100}$*d.*, excluding maintenance of canal.

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$1\frac{1}{4}d.$, *level* railroad with horses.
$2\frac{1}{2}d.$, underground *level* rolley-way with horses.
$2d.$, ordinary underground rolley-way, rope or chain haulage.

If the quantity be small, the rolley-way be level or dipping slightly in favour of the load, and about half-a-mile or under in length, horses can compete favourably with mechanical haulage. But with large quantities, steep gradients, and long distances, mechanical haulage is cheapest.

The following books may be consulted :—Books by André, Callon, Greenwell, already mentioned. Trans. N.E.I., iii. and xvii. The use of steam for canal-boat propulsion, Manchester Assoc. of Eng., Jan. 1886; Proc. I.C.E. xxxi.

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GENERAL PROPERTIES OF AIR AND GASES.

Air and gases may be defined as elastic fluids in contradistinction from liquids which are inelastic fluids.

The elasticity of the air is used to determine the ventilating pressure in a mine by means of the water-gauge.

Air and gases are ponderable, that is to say, they have weight; but the weight of a given volume depends upon its pressure and temperature.

Pressure:—The weight of a given volume of any gas varies as the pressure. In order to find the pressure of the air, we use the barometer.

The standard atmospheric pressure at 32 Fahr. and sea-level = 29·922 in. mer. = 14·696 lbs. per sq. in. = 2,116 lbs. per sq. ft. = 26,213 ft. of homogeneous air column = 33·9 ft. of water column.

To reduce a barometer reading at any point above sea-level to the corresponding reading at sea-level, the following approximate rule is given by Mattieu Williams in "Science in Short Chapters":—

To the observed reading add 0·1″ for each:—
85 ft. up to 510 ft. that the point is above sea-level.
90 ft. from 510 to 1140 ft.
95 ft. from 1140 to 1900 ft.
100 ft. when above 1900 ft.

Thus 28″ at a point 2000 ft. above sea-level = 30·2″ at sea-level.

Correction for temperature:—Mercury expands about 0·0001 of its volume for each degree Fahr. To reduce, therefore, a reading at any temperature to the corresponding reading at the standard temperature of 32°, subtract $\frac{1}{10,000}$ of the observed height for each degree above 32°; or, if the temperature be below 32°, add $\frac{1}{10,000}$ for each degree.

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Depth of pits :

If R = Reading of barometer at lower station.
r = " at higher "
T = Temperature Fahr. at lower station.
t = " at higher "
H = Difference of level in feet.

$$(142.)\quad H = 56{,}300\,(\text{Log. }R - \text{Log. }r)\left(1 + \frac{T+t}{900}\right)$$

$$\therefore\ \text{Log. }R = \frac{H}{56{,}300\left(1 + \frac{T+t}{900}\right)} + \text{log. }r.$$

More simply:

$$(143.)\quad H = 49{,}000\left(\frac{R-r}{R+r}\right)\left(1 + \frac{T+t}{900}\right)$$

$$\therefore\ R = r\left\{\frac{49{,}000\,(900 + T + t) + 900\,H}{49{,}000\,(900 + T + t) - 900\,H}\right\}$$

Very roughly, the mercury rises 1 inch for each 150 fathoms of depth.

Temperature :—The weight of a given volume of any gas varies inversely as its absolute temperature. Absolute temperature = 459 + Fahr. temp.

To find the weight of a given volume of any gas at any known temperature and pressure, 459 cub. ft. of air at 0° Fahr. and bar. 1 in. weigh 1·3253 lbs. Therefore, if

V = Volume of air in cub. ft.
W = Weight in lbs.
I = Barometer in ins.
t = Temperature Fahr.

$$(144.)\quad W = \frac{1{\cdot}3253\,IV}{459 + t}.$$

To find the weight of any other gas, multiply the weight of air by the specific gravity of the gas. See p. 104.

Gas in goaves.—It has been estimated that the air-space in a goaf is equal to about one-sixth of the volume of the coal extracted.

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Absorption of gases by liquids and solids as of air by water in a pump.

Gases enclosed in the pores of coal must be distinguished from the gases that enter into the chemical composition of coal. Sundry analyses of these enclosed, or *occluded gases* as they are called, are given in the following table :—

TABLE XXIV.

GASES ENCLOSED IN THE PORES OF COAL AND EVOLVED IN VACUO AT 212° FAHR.

Name of Colliery.	Quality.	CO_2.	O.	CH_4.	N.	Quantity CC per 100 Grams.	Cubic Feet per Ton.
Navigation	Steam	13·21	0·49	81·64	4·66	250	90
Dunraven	do.	5·46	0·44	84·22	9·88	218	78
Cyfarthfa.........	do.	18·90	1·02	67·47	12·61	147	52
Bute...............	do.	9·25	0·34	86·92	3·49	375	135
Bonville's Court	Anthracite	2·62	...	93·13	4·25	555	199
Watney's.........	do.	14·72	...	84·18	1·10	600	216
Plymouth Iron Works ...	Bituminous.	36·42	0·80	...	62·78	55·9	20
Cwm Clydach...	do.	5·44	1·05	63·76	29·75	55·1	19·8
Bettwys	do.	22·16	6·09	2·68	69·07	24·0	8·6

(Thomas.)

Experiments of Mr. Lindsay Wood on the pressure of gases enclosed in coal. (See Trans. N.E.I., xxx.) The greatest pressure obtained was at Boldon, 461 lbs. per square inch.

TABLE XXV.

Transpiration of Gases.

That is to say, the passage of gases through minute tubes, such as the pores of coal.

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Name of Gas.	Times for Transpiration of equal Volumes.	Velocities of Transpiration.
Oxygen (O)	1·000	1·000
Air..............................	0·9030	1·1074
Nitrogen (N)	0·8768	1·141
Carbonic Oxide (CO)......	0·8737	1·145
Carbonic Acid (CO_2)	0·7300	1·370
Marsh Gas (CH_4)	0·5510	1·815
Ethylene (C_2H_4)	0·5051	1·980
Hydrogen (H)...	0·4370	2·288

(Graham.)

Practical bearing.—Gases flow from green coal into workings. Blowers. Gases assist hewer by breaking down coal.

The Diffusion of Gases.

When two gaseous bodies are mixed together they gradually diffuse themselves through each other; so that, after sufficient time has elapsed for the purpose, whatever may have been their relative densities, they are found intimately blended; the heavier gas does not fall to the bottom, nor does the lighter one rise to the top.

TABLE XXVI.

RELATIVE VELOCITY OF DIFFUSION.

—	Spg.	$\sqrt{\text{Spg.}}$	$\frac{1}{\sqrt{\text{Spg.}}}$	Velocity of Diffusion, Air being taken as unity.
Air	1·000	1·000	1·000	1·000
Hydrogen (H)	0·06926	0·2632	3·7794	3·83
Marsh Gas (CH_4)	0·559	0·7476	1·3375	1·344
Steam (H_2O)...............	0·6235	0·7896	1·2664	...
Carbonic Oxide (CO) ...	0·9678	0·9837	1·0165	1·0149
Nitrogen (N)..............	0·9713	0·9856	1·0147	1·0143
Ethylene (C_2H_4)	0·978	0·9889	1·0112	1·0191
Oxygen (O)	1·1056	1·0515	0·9510	0·9487
Sulphuretted Hydrogen (H_2S)	1·1912	1·0914	0·9162	0·95
Carbonic Acid (CO_2) ...	1·529	1·2365	0·8087	0·812

(Graham.)

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The above table shows that fire-damp mixes with air more readily than stythe does; and fire-damp, therefore, is more easily cleared away by the ventilating current than stythe is.

TABLE XXVII.

FIRE-DAMP ANALYSES.

Name of Colliery.	CH_4.	N.	O.	CO_2.	H.	
Wallsend, from pipe on surface............	92·8	6·9	0·0	0·3	0·0	100·0
Jarrow, Bensham Seam	83·1	14·2	0·6	2·1	0·0	100·0
Hebburn, Do.	86·0	12·3	0·0	1·7	0·0	100·0
Jarrow, Low Main Seam	79·7	14·3	3·0	2·0	0·3	99·3
Jarrow, 5/4 Seam.........	93·4	4·9	0·0	1·7	0·0	100·0
Oakwellgate, Do.	98·2	1·3	0·0	0·5	0·0	100·0
Hebburn, Coal 24 ft. below Bensham ...	92·7	6·4	0·0	0·9	0·0	100·0

(De La Beche and Lyon Playfair.)

Authorities:—"Coal, Mine Gases, and Ventilation," by Thomas. Trans. N.E.I., xxx. Ganot's "Elementary Physics." "Practical Treatise on Gases met with in Coal Mines," by Atkinson. "Practical Treatise on Heat," by Box.

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CHEMISTRY.

Compounds and Elements.

Substances may be divided into three classes.

(1.) Chemical compounds—those substances which can be split up by chemical processes into two or more different materials.

(2.) Chemical elements or simple substances—those which have hitherto resisted all attempts to split them up into two or more different materials. There are at present about 63 of these bodies.

(3.) Mechanical mixtures—substances formed from a mixture of the above.

Atoms.

The atomic *theory* has been adopted to explain the *fact*, that in chemical combinations elements unite in fixed proportions.

An atom is the smallest particle of an element that can *enter into chemical combination* with other elements.

Atoms are incapable of being divided.

The atoms of the same substance are similar to one another and equal in weight.

The atoms of different substances differ in weight.

The weight of the atom of hydrogen being taken as the unit; the atom of oxygen weighs 16, the atom of nitrogen 14, and so on.

Chemical Symbols.

The atoms of the elements are represented by symbols; the first letter of the name being generally taken to express the atom.

Thus, the atom of Oxygen is denoted by O.

„	Nitrogen	„	N.
„	Hydrogen	„	H, etc.

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These symbols represent definite weights of the respective elements. H represents the unit of atomic weight, *i.e.*, the weight of the hydrogen atom, whatever that may be.

O represents a weight of	Oxygen	= 16	Hydrogen atoms.
N ,,	Nitrogen	= 14	,,
C ,,	Carbon	= 12	,,

The symbols and atomic weights of the elements we are interested in are given in the following table :—

TABLE XXVIII.

SYMBOLS AND ATOMIC WEIGHTS.

Name of Element.	Symbol.	Atomic Weight.
Oxygen	O	16
Hydrogen	H	1
Nitrogen	N	14
Carbon	C	12
Sulphur	S	32
Phosphorus	P	31
Chlorine	Cl	35·5
Potassium	K	39
Sodium	Na	23
Calcium	Ca	40
Manganese	Mn	55
Magnesium	Mg	24
Iron	Fe	56
Zinc	Zn	65

Molecules and Formulæ.

The group of atoms forming the smallest particle of a compound which can *exist in a free state*, is called its molecule; and the molecule of a compound is expressed by putting together the symbols of the atoms which compose it. This group of symbols is called a formula.

Thus the molecule of water contains one atom of oxygen, and two atoms of hydrogen, and may, therefore, be expressed by the formula HHO. When, however, several similar atoms are present, the symbol is only written once, and a small

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number is put on the *right* of it, and *a little below*, to show how many atoms are present.

Thus the formula for the molecule of water is H_2O.

When more than one molecule has to be represented a number is placed on *the left* and *level*.

Thus four molecules of water are represented by $4H_2O$.

The molecule of many of the elements consists of two atoms.

Chemical Equations.

Chemical changes are represented by equations.

Thus, $Zn + H_2SO_4 = H_2 + ZnSO_4$ signifies that 65 parts by weight of zinc reacting on 98 parts by weight of sulphuric acid, form 2 parts by weight of hydrogen and 161 parts by weight of zinc sulphate.

Equal volumes of all gases contain, under the same conditions, the same number of molecules; equations, therefore, representing changes in which gases take part, may be read off at once in volumes.

If the volume occupied by one atom of Hydrogen be taken as unity, one molecule of each of the gases will occupy two such volumes. Thus:

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

may be read :—

Two volumes of marsh gas and four volumes of oxygen, form two volumes of carbonic acid gas and four volumes of vapour of water.

The following books may be consulted: "Inorganic Chemistry," W. A. Miller; "Exercises in Practical Chemistry," Harcourt and Madan; "The New Chemistry." International Science Series.

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Oxygen.

Symbol, O; atomic weight, 16.

1,000 cubic feet at 32° Fahr. and bar. 30 in. weigh 89·342 lbs.

Oxygen forms by weight $\frac{8}{9}$ of water, $\frac{1}{4}$ of the atmosphere, and $\frac{1}{2}$ of the solid crust of the earth. It was discovered by Priestley in 1774; and has neither colour, taste nor smell. Oxygen is occasionally found amongst the occluded gases; but principally occurs in mines as a constituent of air. It is essential to life; but, undiluted, it is not fit to be breathed for more than a short time. It supports combustion, and substances which burn in air burn fiercely in oxygen.

It may be prepared from a mixture of potassium chlorate four parts and manganese dioxide one part, mixed together and heated. The whole of the oxygen contained in the potassium chlorate is given off, and a compound of potassium and chlorine remains.

$$\begin{array}{c}\text{Potassium}\\\text{Chlorate}\end{array} = \begin{array}{c}\text{Potassium}\\\text{Chloride}\end{array} + \text{Oxygen.}$$

(145.) $$2KClO_3 = 2KCl + 3O_2.$$

The manganese dioxide is unaltered; in fact, the oxygen could be obtained from potassium chlorate alone; but it is found in practice that the presence of manganese dioxide materially assists the operation.

Carbonic Oxide.

Formula, CO; molecular weight, 28.

1,000 cubic feet at 32° Fahr. and bar. 30 in. weigh 78·305 lbs.

This gas is the result of imperfect combustion. When a body containing carbon is burnt in air, each atom of carbon will combine with two atoms of oxygen to form carbonic

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acid gas; but, if there is not sufficient air to provide two atoms of oxygen for each atom of carbon, that is to say, if the combustion of the carbon is incomplete, carbonic oxide is formed. It has been detected in rare cases amongst the occluded gases; and is also produced by the combustion of coke, charcoal, and gunpowder; and must, in many cases, be one of the constituents of after-damp.

It has neither colour, taste, nor smell, but is exceedingly poisonous; ½ per cent. in the air, if breathed for long, producing fatal results. It does not support combustion, but itself burns with a blue flame, forming CO_2.

It may be prepared from hydrogen oxalate, treated with hydrogen sulphate. Carbonic oxide and carbonic acid are driven off, the latter of which is removed by passing the mixture through a solution of potassium hydrate; but, as this gas is very poisonous, it is best not meddled with by unskilled persons.

$$\begin{array}{ccccccccccc} \text{Hydrogen Oxalate} & + & \text{Hydrogen Sulphate} & = & \text{Carbonic Oxide} & + & \text{Carbonic Acid} & + & \text{Water} & + & \text{Hydrogen Sulphate.} \end{array}$$

$$(146.)\quad H_2C_2O_4 + H_2SO_4 = CO + CO_2 + \overbrace{H_2O + H_2SO_4}$$

Hydrogen.

Symbol, H; atomic weight, 1.

1,000 cubic feet at 32° Fahr. and bar. 30 in. weigh 5·5832 lbs.

Hydrogen has neither colour, taste, nor smell. It is very inflammable, burning with an almost colourless flame. If breathed in its undiluted state, it quickly causes a very disagreeable sensation; but this is due to the exclusion of oxygen from the lungs, and not to the properties of hydrogen, which is not poisonous, and may be breathed when diluted with ten times its volume of air, for a considerable time, without experiencing any ill effect.

The experiments of Meyer and Thomas show that, in an explosion of marsh gas and air, the whole of the marsh gas is broken up; and, if there be too little air to form carbonic acid gas and water, carbonic oxide and hydrogen are formed.

It may be prepared by treating zinc with hydrogen sul-

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phate. The hydrogen is driven off, and zinc sulphate is left behind.

$$\text{Zinc} + \begin{matrix}\text{Hydrogen}\\\text{Sulphate}\end{matrix} = \text{Hydrogen} + \text{Zinc Sulphate.}$$

$$(147.)\quad Zn + H_2SO_4 = H_2 + ZnSO_4.$$

Combined with carbon in the proportion of 4 parts by weight of hydrogen to 12 of carbon, it forms marsh gas, the principal constituent of fire-damp.

Hydrogen Sulphide.

Formula, H_2S; molecular weight, 34.

1,000 cubic feet at 32° Fahr. and bar. 30 in. weigh 94·92 lbs.

Hydrogen sulphide, or sulphuretted hydrogen as it is more generally called, is a colourless gas, but has a strong smell not unlike that of rotten eggs. It is "generated in small quantity in coal mines, more especially in old-worked portions, which are partly filled with water. By the action of oxygen dissolved in water, sulphates are formed; props in undergoing decomposition in water break up the sulphate of lime and assimilate its oxygen, the sulphur seizing probably the hydrogen of the wood to form hydrogen sulphide." (Thomas's "Coal, Mine Gases, and Ventilation," p. 204.)

It does not support combustion, but is itself inflammable, forming water and sulphurous anhydride ($H_2O + SO_2$). Breathed in an undiluted state, it is fatal to life; and, when diluted with ten times its volume of air, it produces sickness, giddiness, weakness, and loss of sensation.

This gas may be prepared from proto-sulphide of iron treated with dilute hydrogen chloride. Hydrogen sulphide will be given off, and iron chloride formed.

$$\begin{matrix}\text{Iron Proto}\\\text{Sulphide}\end{matrix} + \begin{matrix}\text{Hydrogen}\\\text{Chloride}\end{matrix} = \begin{matrix}\text{Iron}\\\text{Chloride}\end{matrix} + \begin{matrix}\text{Hydrogen}\\\text{Sulphide.}\end{matrix}$$

$$(148.)\quad FeS + 2HCl = FeCl_2 + H_2S.$$

Nitrogen.

Symbol, N; atomic weight, 14.

1,000 cubic feet at 32° Fahr. and bar. 30 in. weigh 78·175 lbs.

Nitrogen has neither colour, taste, nor smell, and is incapable of supporting combustion or animal life, but is not

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poisonous, causing death when breathed only by excluding oxygen from the lungs. It is found in large quantities amongst the gases occluded in some coals; but occurs principally in mines as a constituent of air.

Mixed with oxygen, it forms air, and the readiest way of obtaining it for experiment is to withdraw the oxygen by the action of some substance which has an affinity for oxygen and not for nitrogen. Phosphorus is convenient for this purpose, since it readily combines with oxygen; and the compound formed, phosphorus pentoxide (P_2O_5), is soluble in water, and is, therefore, quickly absorbed when the experiment is made over the pneumatic trough, leaving the nitrogen nearly pure.

Carbonic Acid Gas.

Formula, CO_2; molecular weight, 44.

1,000 cubic feet at 32° Fahr. and bar. 30 in. weigh 128·45 lbs.

Carbonic acid gas has neither colour nor smell, but an acid taste. It is found in large quantities amongst the gases occluded in some coals; but is also produced in mines by the respiration of men and animals, by the burning of candles and lamps, and by the oxidation of the coal and other substances.

It extinguishes lights, and is fatal to animal life.

It may be prepared by the decomposition of marble by hydrogen chloride. Carbonic acid gas is given off, calcium chloride and water are formed in the vessel.

$$\text{Marble} + \begin{matrix}\text{Hydrogen}\\\text{Chloride}\end{matrix} = \begin{matrix}\text{Carbonic}\\\text{Acid Gas}\end{matrix} + \begin{matrix}\text{Calcium}\\\text{Chloride}\end{matrix} + \text{Water.}$$

$$(149.)\quad CaCO_3 + 2HCl = CO_2 + CaCl_2 + H_2O$$

Fire-Damp.

Marsh gas. Formula, CH_4; molecular weight, 16.

1,000 cubic feet at 32° Fahr. and bar. 30 in. weigh 45·22 lbs.

Fire-damp is a mixture of several gases, its principal constituent being marsh gas, CH_4; but its composition varies at different collieries, as see p. 105; and, in addition to these gases, coal-dust is often present. It is only found in mines as an occluded gas.

Marsh gas may be prepared by heating a mixture of sodic

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acetate and sodic hydrate in an iron tube. Marsh gas is driven off and sodic carbonate is formed in the tube.

$$\begin{array}{lccccccc} & \text{Sodic Acetate} & + & \text{Sodic Hydrate} & = & \text{Sodic Carbonate} & + & \text{Marsh Gas.} \\ (150.) & NaC_2H_3O_2 & + & NaHO & = & Na_2CO_3 & + & CH_4. \end{array}$$

For making experiments, ordinary coal gas may be used, though it differs in composition from average specimens of fire-damp.

TABLE XXIX.

COMPOSITION OF FIRE-DAMP AND COAL GAS.

	CH_4.	H.	CO.	CO_2.	C_2H_4.	N.
Fire-damp...	94·0	0	0	1·0	0	5·0
Coal Gas ...	42·0	42·0	4·5	0	9·0	2·5

The exact effects of fire-damp upon combustion and animal life depend upon its composition, temperature, and density; but, speaking generally, at ordinary temperatures and pressures, when mixed with 3·5 times its volume of air, it does not explode, but burns quietly; with 5·5 volumes of air, it explodes slightly; and with about 9½ volumes of air the explosion is the greatest. With 13 volumes of air, it explodes feebly; with 30 volumes of air, it will show plainly on the lamp; with 50 volumes of air, it can just be detected on the lamp by a skilful observer. If breathed in an undiluted state, it would soon cause death; but, mixed with twice its own volume of air, it may be breathed for some time without ill effects.

An explosion of marsh gas and air by volume.

(1) Suppose we have of CH_4 2 volumes.
(2) C requires O_2 = 2 volumes of oxygen forming 2 volumes of CO_2.

H_4 also requires $O_2 = 2$ volumes of oxygen forming 4 volumes of H_2O.

(3) CH_4 ∴ requires 4 volumes of oxygen. But 1 volume of air contains ·21 volumes of oxygen.

∴ 19 volumes of air will be required for 4 volumes of oxygen.

∴ 19 volumes of air are required for 2 volumes of CH_4.

∴ $9\frac{1}{2}$ volumes of air are required for 1 volume of CH_4.

And the composition of the after-damp is 1 volume CO_2 + 2 volumes H_2O (steam) + $7\frac{1}{2}$ volumes N.

In practice, the exact composition of the after-damp will depend upon the composition of the explosive mixture. In every case the whole of the marsh gas will be broken up and—if there be insufficient oxygen to consume all the marsh gas and coal dust, if the last be present—some carbonic oxide and hydrogen will be formed. In all probability, carbonic oxide is formed in the majority of explosions in mines. (Thomas's "Coal, Mine Gases, and Ventilation," p. 323.)

The force developed by an explosion of marsh gas and air depends upon a multitude of circumstances, many of which cannot be determined in the case of an explosion in a mine. But in the case of a mixture of marsh gas and air in the most explosive proportions, and enclosed in a strong vessel, we can calculate the force developed, as follows:—

1 lb. of CH_4 burning to CO_2 and H_2O yields about 23,550 units of heat. (See p. 34.)

Let the initial temperature be 62° Fahr. = 521° absolute.

1 lb. CH_4 = 12 oz. C + 4 oz. H.

12 oz. C + 32 oz. O = 2·75 lbs. CO_2.

4 oz. H + 32 oz. O = 2·25 lbs. H_2O.

And 64 oz. O are contained in about 17 lbs. air.

We have then, taking specific heat at constant volume. (See p. 33.)

CO_2	2·75 × ·1711 =	·470	units of heat to raise	2·75 lbs. CO_2 one deg.
H_2O	2·25 × ·364 =	·819	do.	2·25 lbs. H_2O one deg.
N	13·00 × ·1727 =	2·245	do.	13·00 lbs. N one deg.
	18·00	3·534		18·00

Then the degrees the mixture will be raised are $\frac{23550}{3.534}$ $= 6663°$ Fahr. and the volume it will seek to attain $= \frac{521 + 6663}{521} = 13.8$, *i.e.*, the steady pressure due to the explosion $= 13.8$ atmospheres; but to this must be added a considerably increased force due to shock, the amount of which cannot be calculated. When it is remembered that 13·8 atmospheres are equal to 30,000 lbs. per sq. ft., whereas the force of a hurricane moving at the rate of 100 miles an hour is only 50 lbs. per sq. ft., some idea of the terrific force of an explosion may be realised.

At the Haswell Explosion, in 1844, Faraday and Lyell drew attention to the part that coal dust might play in an explosion; but, though the question has cropped up from time to time since, it is only recently that the matter has been thoroughly investigated. Mr. Galloway has, within the last few years, proved that an explosion may be caused with coal dust and air, without the presence of any gas. (See Trans. Royal Soc. 1876—1884, and "Nature," 6th Nov., 1884.) And it is now admitted that many of the most violent explosions of recent years were due in part, if not entirely, to coal dust. (See "Explosions in Coal Mines," by Atkinson.)

The detection of fire-damp is usually effected with the Davy lamp; but, since it has been shown by Sir Frederick Abel that, if coal dust be present, 1·5 of gas in the air will render the mixture explosive, a more delicate test is required. The following detectors are described in the Trans. N.E.I., viz.:—Ansell's, vol. xv.; Steavenson's, vol. xxvi.; Liveing's vol. xxvii.; Forbe's, vol. xxix.; and Maurice's, vol. xxxvi. Chatellier has introduced a lamp with screen and two shields for the same purpose.

Methods of dealing with Fire-damp.

Removal by :—Firing, now no longer practised. Drainage of goaves by pipes to the upcast (see Faraday and Lyell's report on the Haswell Explosion), or by bore-holes to the surface; both impracticable. Drainage of whole coal by

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bore-holes and gas drifts in a higher seam might answer in certain cases.

Dilution with air. (See General Rules 1.)

Absence of heat:—Heat is required for light and for shot-firing. The steel mill of Spedding about 1740. Reflected light, and fish-skins have been tried.

The safety lamp due to Clanny, 1811; Davy and Stephenson, 1815. The safety of the lamp depends upon the fact that metal gauze permits air and light to pass but not flame. The conducting power of the gauze is impaired by overheating, broken wires, dirt, or exposure to a current of gas.

The maximum of safety, combined with the maximum of light, is obtained from gauze with wires $\frac{1}{60}$ to $\frac{1}{40}$ in. dia., and spaced with 28 apertures to the linear inch.

The best-known lamps are the Davy, Geordie, Clanny, Mueseler, Tin-can, and Marsaut lamps.

The Accidents in Mines Commission (1886) report most favourably of the following:—Gray's, Marsaut's, the Bonneted Mueseler, and Evan Thomas's modification of the bonneted Clanny.

Swan's portable electric miners' lamp gives a good and perfectly safe light; but it is too costly for practical use, and will not indicate the presence of carbonic acid gas.*

In the Author's opinion, too much attention is paid to securing lamps from the action of violent currents to which they are very unlikely ever to be exposed; whilst their illuminating power, a daily necessity, is too much neglected. Inventors appear to forget the importance of a good light all round, including the roof. About 42°/₀ of the fatal accidents in mines are due to falls of roof and sides, as against 24°/₀ due to explosions, and a very small proportion of these last have been traced to the safety-lamp.

Shot-firing has already been dealt with under the head of explosives.

Ambulance Classes.

The St. John's Ambulance Association have established classes at many colliery villages, with excellent results. The

* It is described, together with the fire-damp detector attached, in Trans. N.E.I. xxxv.

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following are short and clear instructions for the recovery of persons suffocated in mines.

Asphyxia.

Miners are exposed to asphyxia when the circulation of the air is not sufficiently active, when the mine exhales a quantity of deleterious gas, when they imprudently penetrate into ancient and abandoned workings, and when there is an explosion.

The symptoms of asphyxia are sudden cessation of the respiration, of the pulsations of the heart, and of the action of the senses; the countenance is swollen, and marked with reddish spots, the eyes are protruded, the features are distorted, and the face is often livid, &c.

The best and first remedy to employ, and in which the greatest confidence ought to be placed, is the renewal of the air necessary for respiration. In succession:—

1. Promptly withdraw the asphyxiated person from the deleterious place, and expose him to pure air.

2. Loosen the clothes round the neck and chest; and dash cold water in the face and on the chest.

3. Attempts should be made to irritate the pituitary membrane with the feathered end of a quill, which should be gently moved in the nostrils of the insensible person, or to stimulate it, with a bottle of volatile alkali placed under the nose.

4. Keep up the warmth of the body, and apply mustard plasters over the heart and round the ankles.

5. If these means fail to produce respiration Dr. Sylvester's method of producing artificial respiration should be tried, as follows:—

Place the patient on the back on a flat surface inclined a little upwards from the feet; raise and support the head and shoulders on a small firm cushion or folded article of dress placed under the shoulder-blades. Draw forward the patient's tongue and keep it projecting beyond the lips; an elastic band over the tongue and under the chin will answer this purpose, or a piece of string or tape may be tied round

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them, or by raising the lower jaw the teeth may be made to retain the tongue in that position. Remove all tight clothing from about the neck and chest, especially the braces. Then standing at the patient's head, grasp the arms just above the elbows, and draw the arms gently and steadily upwards above the head, and keep them stretched upwards for two seconds (by this means air is drawn into the lungs). Then turn down the patient's arms and press them gently and firmly for two seconds against the sides of the chest (by this means air is pressed out of the lungs). Repeat those measures alternately, deliberately, and perseveringly about fifteen times in a minute, until a spontaneous effort to respire is perceived; immediately upon which cease to imitate the movements of breathing, and proceed to induce circulation and warmth.

6. To promote warmth and circulation rub the limbs upwards with firm grasping pressure and energy using handkerchiefs, flannels, &c. Apply hot flannels, bottles of hot water, heated bricks, &c., to the pit of the stomach, the arm pits, between the thighs, and to the soles of the feet.

7. On the restoration of life a teaspoonful of warm water should be given; and then, if the power of swallowing has returned, small quantities of wine, warm brandy and water, or coffee should be administered.

8. These remedies should be promptly applied, and, as death does not certainly appear for a long time, they ought only to be discontinued when it is clearly confirmed. Absence of the pulsation of the heart is not a sure sign of death, neither is the want of respiration.

Illuminating Gas.

Illuminating gas is not found in mines; but, as it is an important product of the distillation of coal and is largely used about collieries, it will be as well to say a word about it here.

Its specific gravity depends upon the proportion of the heavier hydrocarbons present; in other words, specific gravity is a test of illuminating power.

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12	candles gas is about		0·405	specific gravity.	
14	"	"	0·430	"	"
16	"	"	0·455	"	"
18	"	"	0·482	"	"
20	"	"	0·508	"	"
22	"	"	0·537	"	"

Its composition is variable, that of an average specimen is given on p. 113.

The volume produced from a ton of coal depends upon the composition of the coal, as see Table XXX.

TABLE XXX.

AVERAGE PRODUCE OF A TON OF COAL.

——	Newcastle Coal.	Wigan Coal.	Wigan Cannel.
Gas, cubic feet	9,500	9,980	10,900
Candle power	13	11·4	21·25
Coke, lbs.	1,540	1,517	1,436
Tar, gallons	9	11	17
Ammoniacal liquor, gallons	10	20	18

("Gas Manager's Pocket Book.")

Air.

1,000 cubic feet of air at temp. 32° Fahr. and 30 in. bar. weigh 80·9 lbs.

Air is a mixture of oxygen and nitrogen, with traces of some other gases, and vapour of water. Its composition varies a little in different places.

100 cubic feet of pure dry air contain :—

Oxygen	20·99	cub. ft.
Nitrogen	78·98	"
Carbonic Acid Gas	0·03	"
	100·00	cub. ft.

(Angus Smith.)

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100 cubic feet of ordinary air contain :—

Oxygen	20·61 cub. ft.
Nitrogen	77·95 ,,
Carbonic Acid . . .	0·04 ,,
Vapour of Water . . .	1·40 ,,
	100·00 cub. ft.

Ammonia	Traces.
Nitric Acid	Traces.
Carburetted Hydrogen .	Traces.
Sulphuretted Hydrogen .	Traces in large towns.
Sulphur Dioxide . . .	Traces in large towns.

Besides these gases, minute particles of solid matter are always present.

Sundry Analyses by Angus Smith :—

LONDON.

Most Oxygen, Belsize Park .	21·010 per cent.
Least Oxygen, Lambeth . .	20·795 ,,
Badly Ventilated Law Court .	20·49 ,,
Least CO_2 (open spaces) . .	0·0334 ,,
Most CO_2 (gallery of theatre) .	0·32 ,,

METROPOLITAN RAILWAY.

Oxygen...20·7...Carbonic Acid . 0·1452 ,,

MINES.

	Average of 339 Mines.	Worst of 339 Mines.	Average of 8 Coal Mines.	Worst of 8 Coal Mines.
O ...	20·26 ...	18·27 ...	20·74 ...	20·44
CO_2...	0·786 ...	2·73 ...	0·24 ...	0·42

Analyses of air in the returns of 9 Mines in Saxony, by Dr. Winkler :—

N.	75·6174	to	78·565	% by vol.
O.	17·751	to	19·689	,,
CO_2.	0·1168	to	2·716	,,
H_2O.	2·5254	to	4·1904	,,
CH_4.	0·01754	to	0·25576	,,

(N.E.I., xxxii., abs. p. 25.)

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Purification by:—Diffusion, the wind, rain, plants, and animals.

Vitiation by:—Withdrawal of oxygen, as in the breathing of men and horses; the combustion of lamps, candles, and gunpowder; the conversion of iron pyrites into sulphate of iron, $2FeS_2 + 4O_2 = 2FeSO_4 + S_2$; the oxidation of small coal; &c., &c. And Vitiation by the introduction of foreign substances, such as the occluded gases, the products of combustion and respiration, vapour of water, and coal dust.

Angus Smith considers that two miners, using ½ lb. candle and 12 oz. of powder, will produce 25½ cub. ft. of CO_2 in 8 hours. Thomas, quoting Boussingault, says that a horse will produce 155 cub. ft. of CO_2 in 24 hours. But the quantity, both in men and horses, is very variable, and, as certain organic exhalations are also given off in breathing which, though they may not be capable of detection by chemical analysis, are more deleterious than CO_2, no estimate of the volume of air required can be formed from an attempt to calculate the CO_2 produced.

The quantity of air required depends upon the conditions of each mine. In the North of England, the volume seems to vary from 100 to 500 cubic feet per min. per person employed, and from 30 to 160 cubic feet per min. per ton of coal worked per day. The velocity in the workings should be about 4 feet per second.

Authorities:—"Air and Rain," Angus Smith; The Chesterfield and Derbyshire Inst. Trans., x.; "Coal and its Uses," Green, Miall, etc.; Papers by Davy, communicated to the Royal Soc. (See Royal Soc. Trans., 1816.) The Report of the Select Com., 1835; The Journal of the British Soc. of Mining Students, vi.; J. J. Atkinson on "Ventilation;" also, Papers by the same author in the Transactions of the North of England Institute; "Ventilation of Coal Mines," Fairley; "Coal, Mine Gases, and Ventilation," Thomas; J. Wales' Papers, Trans. N.E.I., vi. and vii.; "Hist. of Coal Mining," Galloway; Proceedings Royal Soc., xxiv. to xxxvii.; Report of the Accidents in Mines Commission, 1886; "Explosions in Coal Mines," Atkinson; "Ambulance Lectures," Weatherly; and "Shepherd's First Aid to the Injured," Bruce.

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VENTILATION.

A Wind, either upon the surface or in the mine, results from a difference of pressure; the air passing from the place where the pressure is high to the place where the pressure is low.

If H = Height in feet of a column of air of the density of the flowing air that will, by its weight, produce the difference of pressure.

V = Velocity of the wind in feet per second.

$$(151.)\ H = \frac{V^2}{64} \quad \therefore\ V = 8\sqrt{H}.$$

This formula applies to all fluids, H being taken in feet of the fluid in question.

In practice the actual velocity of an air current is much retarded by friction; and it is, therefore, necessary to study the laws that govern the resistance that air meets with in mines.

The Three Laws of Friction.*

(1) The pressure required to overcome the friction of the air increases and decreases in exactly the same proportion that the area or extent of the rubbing surface, exposed to the air, increases or decreases.

If P = the ventilating pressure,
L = the length of a drift,
O = the perimeter, do.
Then LO = the rubbing surface,
And P varies as LO.

(2) The pressure per unit of area required to overcome

---

* P also varies as the density of the air; but the variations in density are so small that this may be neglected.

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the friction of the air increases and decreases inversely as the sectional area of the drift increases and decreases.

If P = the ventilating pressure per unit of sectional area of the drift,
A = the sectional area of the drift,

Then P varies as $\frac{1}{A}$

(3) The pressure required to overcome the friction of the air increases and decreases in the same proportion that the velocity squared of the air increases and decreases.

If P = the ventilating pressure,
V = the velocity of the air,
Then P varies as V^2.

It follows from this that if P = the ventilating pressure per unit of sectional area,

(152.) $P = \frac{KLOV^2}{A}$

P may be obtained by means of a very delicate barometer, or by means of a water-gauge; L, O, A, and V, by measurement, treating each section of the mine separately. K is a constant to be found by experiment: it depends upon the units used. It is called the coefficient of friction; and is equal to the ventilating pressure required to overcome the resistance that a unit of air flying with unit velocity would meet with in circulating round a mine of unit area, and having unit rubbing surface.

When P	is taken in lbs.	per square foot.
L	do.	feet.
O	do.	feet.
V	do.	feet per minute.
A	do.	in square feet.

According to the experiments of MM. Devillez, Raux, &c., K = 0·000,000,009,36 (approximately) for the whole of a mine; but, in the case of clear smooth shafts alone, K = 0·000,000,003,6.

That is to say a ventilating pressure of 0·000,000,009,36 lbs.

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per sq. ft. would be required to force 1 c. f. per min. through a mine 1 sq. ft. in area, and having a rubbing surface of 1 sq ft.

It is more convenient to take V in thousands of feet per min.; in which case $K = 0{\cdot}009{,}36$ and $0{\cdot}003{,}6$ respectively.

A great many important facts may be deduced from formula (152), as see Fairley's "Ventilation of Coal Mines."

The Equivalent Orifice.—Air in passing through an opening in a thin plate meets with resistance; and M. Murgue has pointed out the convenience of assimilating the workings of a mine to such an opening in calculations for ventilating purposes. This opening he has named *the equivalent orifice.*

To find the equivalent orifice for any given mine :—

Let Q = Quantity of air in cubic feet per second passing through the opening (*i.e.*, circulating round the mine).

h_a = Ventilating pressure in feet of air column, required to overcome the resistance of the mine.

A = opening in thin plate in square feet (*i.e.*, equivalent orifice).

k = coefficient of contraction of orifice (*i.e.*, Vena contracta) = ·65.

Then—

$$Q = \sqrt{2gh_a} \times kA = \sqrt{2gh_a} \times \cdot 65A.$$

$$(153.) \therefore A = \frac{Q}{\cdot 65\sqrt{2gh_a}}$$

But it is often more convenient to use the following units, viz. :—

Q in thousands of cubic feet per minute.

h_a in inches of water gauge.

When the formula becomes—

$$(154.)\ A = \frac{0{\cdot}37Q}{\sqrt{h_a}} \therefore Q = \frac{A\sqrt{h_a}}{0{\cdot}37} \text{ and } h_a = 0{\cdot}1369\left(\frac{Q}{A}\right)^2$$

The average value of A for English mines is said to be about 20, and for Belgian 8·6 sq. feet.

In order to find the quantity of air passing through a

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drift, we must first find its velocity, and this is not easy, because the velocity varies in different parts of the same section of a gallery. The mean velocity may be found by dividing the section into squares with thin strings, each square about one foot in area, taking the velocity in each, and averaging them. M. Aguillon points out that, as the ratio between the mean velocity and the velocity at any given point of the same section is constant, it is only necessary to find this ratio once for all for any one convenient point in the section, and, in future, to measure the velocity at that point only.

A Difference of Pressure may be produced by:—

(A.) Reducing the density of the air in the upcast shaft (depressive, exhaustive, or negative ventilation) by means of:—

(i.) The natural heat of the mine.
(ii.) Furnace.
(iii.) Steam jet.
(iv.) Exhaust-fans.
(v.) Varying capacity machines.

(B.) Increasing the density of the air in the downcast shaft (compressive, blowing, or positive ventilation) by means of:—

(i.) Air-pump.
(ii.) Water-fall.
(iii.) Wind-cowl.
(iv.) Blowing-fans.
(v.) Varying capacity machines.

The first, Depressive Ventilation, is that adopted in practice almost without exception, though it is not easy to say why, except that the downcast is usually the drawing shaft, and it would not be convenient to have a ventilating machine upon it.

(A.) Depressive Ventilation.

(i.) *The Heat of the Mine* gives rise to what is usually called *natural ventilation*, and is the only means used for setting up a current of air in most metal mines. For the

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temperature of the strata at any given depth, see p. 77. In making calculations of the artificial pressure required in any case, the pressure due to the heat of the mine must not be forgotten. The formulæ below for the furnace are equally applicable to natural ventilation.

(ii.) *The Furnace:—*

If M = motive column (ventilating pressure) in feet of air of the temperature of the air in the upcast.

D = depth of upcast in feet (upcast column of heated air.)

t, T, t' = temperature of air in downcast, upcast, and returns respectively.

P = ventilating pressure in lbs. per square foot.

I = height of barometer in inches.

W = weight of one cubic foot of the return air in lbs.

Q = cubic feet of air per minute in the main return.

X = lbs. of coal burnt per hour.

Y = area of furnace in square feet.

Then—

$$(155.)\quad M = D \times \frac{T - t}{459 + t}$$

$$(156.)\quad T = \left\{ \frac{1{\cdot}3253 \times I \times D}{\frac{1{\cdot}3253 \times I \times D}{459 + t} - P} \right\} - 459.$$

$$(157.)\quad X = \left\{ \frac{WQ \times (T - t') \times 0{\cdot}238 \times 60}{14{,}000} \right\} \times \text{say } 2.$$

$$(158.)\quad Y = \frac{X}{10}\ \text{(roughly.)}$$

$$(159.)\quad P = \left(\frac{1{\cdot}3253 \times I}{459 + t} - \frac{1{\cdot}3253 \times I}{459 + T.} \right) \times D.$$

No more air should pass through the furnace than is required for combustion, viz.:—About 300 cub. ft. per lb. of coal burned. In theory only about 150 cub. ft. are required.

The furnace should be placed as low down in the mine as possible, and should be built with coolers to prevent ignition of the seam.

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As the heating of the air in the upcast dilates it; if the air be heated above a certain temperature its volume will become so great, and consequently its velocity in the upcast so high, that the resistance due to friction in the upcast will more than balance the increased ventilating pressure due to the increased temperature; and when this point is reached, the *more* the air in the upcast is heated the *less* will be the air circulated through the workings. Peclet considers that when the air in the upcast is expanded to twice its original volume the limit of furnace ventilation is reached.

The volume of air may be increased by building a cupola on to the upcast shaft.

If R = ratio that the volume of air required bears to the volume circulating.

D = depth of upcast in feet.

H = height in feet of cupola.

(160.) $H = (R^2 - 1) D$.

TABLE XXXI.

CONSUMPTION OF FUEL ON PIT FURNACES.

——	Depth.	Coals per H.P. utilised per hour, excluding power due to heat of mine.	Coals per H.P. utilised per hour, including power due to heat of mine.	Quantity of air per min.
	feet.	lbs.	lbs.	cubic feet.
Thornley 5/4 Seam ...	556	85·5	37·5	45,756
Thornley Hutton Seam	868	162·4	57·1	26,574
Walker	960	30·5	15·6	44,800
Castle Eden	1,038	29·1	28·3	42,326
South Hetton............	1,212	27·2	15·5	132,895
Wearmouth...............	1,800	29·5	7·9	70,500
Average.........		60·7	27·6	

(Trans. N.E.I., vi.)

(iii.) *The steam jet*:—If placed near the top of the pit will produce a current by pushing up the air above it; and the *maximum* units of work that it can yield will be given by formula (51), viz.:—U = PV. But if this steam were

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used with expansion in an engine to drive a fan the units of work *actually got in practice* would be more than PV. The steam jet, therefore, placed near the top of the shaft, cannot compete with a fan.

If placed at the bottom of the shaft it would also heat the upcast column of air; but the volume passing up the shaft would be augmented by the volume of the steam used, *i.e.*, the velocity and friction would be increased; and there would probably be some condensation and consequent downpour of water tending to reverse the current.

In practice it is found that the steam jet does not give such good results as the furnace. On the other hand, it cannot fire gas, and might (like the water fall) be used as a temporary expedient.

(iv.) *Fans* may be either centrifugal fans; or screw fans, as The Pelzer (see Trans. N.E.I., xxxi., abs. p. 9); about these last I do not propose to say anything.

Centrifugal Force:—

If F = Centrifugal force in lbs.
W = Weight in lbs.
V = Velocity in feet per second.
R = Radius in feet.
g = Force of gravity, say 32.

(161.) $$F = \frac{w}{g} \times \frac{V^2}{R}.$$

Centrifugal Fans.—These are either made of a large diameter, to run at a low velocity, as the Guibal and Waddle; or of a small diameter, to run at a high velocity, as the Bowlker, Capell, and Schiele. But the fundamental principle is the same in all, the work done depending upon the speed of the periphery, or tangential velocity as it is usually called.

Let H = gross ventilating pressure (theoretical depression) expressed in feet of air column of the density of the flowing air.

u = Tangential velocity of fan in feet per second.

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Then, in a theoretically perfect fan :—

(162.) $H = \frac{u^2}{g}$

But we have already seen formula (151) that $H = \frac{V^2}{64}$ *i.e.*, $= \frac{V^2}{2g}$. We may say, therefore, that :—In a perfect fan the theoretical depression is double the height due to the tangential velocity.

If H = as above.
P = Ventilating pressure in lbs. per sq. ft.
WG = Water gauge in inches.
d = density of water = 1000.
d′ = density of air = 1·2 approx. at ordinary pressure and temperature.

Then—

(163.) $P = 5{\cdot}2\ WG \therefore WG = \frac{P}{5{\cdot}2}$

(164.) $H = \frac{d\ WG}{d' \times 12} = \frac{1{,}000WG}{1{\cdot}2 \times 12} \therefore WG = \frac{1{\cdot}2 \times 12H}{1{,}000}$

The following formulæ are taken from Mr. A. L. Steavenson's translation of M. Murgue's work, to which students are referred for details :—

Let H = the theoretical depression in feet of air column that a perfect fan would give if its eye were shut off from the mine and atmosphere.

h_a = effective depression in feet of air column; *i.e.*, the ventilating pressure required to overcome the resistance of the workings = the water gauge in the fan drift.

h_0 = useless depression in feet of air column; *i.e.*, the ventilating pressure required to overcome the resistance the air meets with in passing through the fan. To obtain this the communication between the fan-eye and the workings must be closed, and the eye connected direct with the atmosphere.

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Q = Quantity of air in cubic feet per second.
A = Equivalent orifice in sq. ft. (see p. 124).
O = Orifice of passage in sq. ft.; *i.e.*, the area of a hole in a thin plate which would offer the same resistance to the air that the fan offers.
k = coefficient of efficiency of fan (varying in the case of well designed fans from 0·5 to 0·8).
g = gravity, say 32·19.
u = Tangential speed of fan in feet per second.

Then—

(165.) $H = h_a + h_o$

(166.) $H = \dfrac{u^2}{g}$

(See 153.) $A = \dfrac{Q}{0{\cdot}65\sqrt{2gh_a}}$

(167.) $O = \dfrac{Q}{0{\cdot}65\sqrt{2gh_o}}$

(168.) $h_a = \dfrac{Q^2}{2g\,(0{\cdot}65A)^2}$

(169.) $h_o = \dfrac{Q^2}{2g\,(0{\cdot}65O)^2}$

(170.) $Q = 0{\cdot}65A\sqrt{2gh_a}$

(171.) $Q = 0{\cdot}65O\sqrt{2gh_o}$

(172.) $\dfrac{h_o}{h_a} = \dfrac{A^2}{O^2}$

(173.) $h_a = \dfrac{H}{1 + \dfrac{A^2}{O^2}}$

174.) $Q = \dfrac{0{\cdot}65A\sqrt{2gH}}{\sqrt{1 + \dfrac{A^2}{O^2}}}$

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And for practical calculations :—

$$(175.)\ h_a = \frac{ku^2}{g\left(1+\frac{A^2}{O^2}\right)}$$

$$(176.)\ Q = \frac{0{\cdot}65\sqrt{2kAu}}{\sqrt{1+\frac{A^2}{O^2}}}$$

I believe Nasmyth was the first to apply the fan to ventilating purposes. His machine was an open running fan with straight blades, and gave a very small efficiency. To Guibal belongs the greater part of the credit for our present, comparatively speaking, perfect machine.

If Q = total volume of air circulating in a mine.
q = a portion of Q due to any cause, say a fan.
v = the rest of Q due to some other cause, say a furnace.

$$(177.)\ Q = \sqrt{q^2+v^2}$$

(v.) *Varying Capacity Machines.**—See description of Lemielle's, Nixon's, Struvé's, Cooke's, and Roots' blowers in Trans. N.E.I., i., vi., xi., xvi., xviii., xix., xxx.

(B.) Compressive Ventilation.

This has been tried in Germany (see Trans. N.E.I. xxxiv. abs. p. 49), though not in England, so far as I am aware. Many persons consider that such a method of ventilation would be preferable to the exhaustive system. (See *Colliery Guardian*, 1880, 2d part.) The waterfall is convenient as a temporary expedient; and either the water-fall or wind-cowl may be used for the permanent ventilation of a small non-fiery mine.

* These machines are best suited to mines with small equivalent orifices (less than 20 sq. ft.). There are not many of them in use in England.

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Relation between Volume, Pressure, &c.

The ventilating pressure varies as :—

The depth of the upcast shaft (furnace ventilation).

The difference of temperature between upcast and downcast.

The HP of the ventilating machine or furnace.

The quantity of coals burned.

The quantity of air circulating varies as :—

The revolutions of the fan.

The tangential velocity of the fan.

The $\sqrt[3]{\text{of the ventilating pressure}}$.

The $\sqrt[3]{\text{of the depth of the upcast (furnace ventilation)}}$.

The $\sqrt[3]{\text{of the difference of temperature}}$ (nearly, as see p. 126).

The $\sqrt[3]{\text{of the HP of the ventilating machine}}$.

The $\sqrt[3]{\text{of the coals burned}}$.

Authorities :—Trans. N.E.I., i. and vi., on the Steam Jet; xviii. and xix., on the Furnace; xxvi. and xxxi., on the Fan; Books and Papers by Fairley and Atkinson already mentioned; Murgue's "Theory and Practice of Centrifugal Ventilating Machines," by A. L. Steavenson.

TABLE XXXII.

TABLE OF HYPERBOLIC LOGARITHMS (FORMULÆ 61, 85, ETC.).

Nos.	Logarithm	Nos.	Logarithm	Nos.	Logarithm	Nos.	Logarithm
1·01	·009	1·11	·104	1·21	·190	1·31	·270
1·02	·019	1·12	·113	1·22	·198	1·32	·277
1·03	·029	1·13	·122	1·23	·207	1·33	·285
1·04	·039	1·14	·131	1·24	·215	1·34	·292
1·05	·048	1·15	·139	1·25	·223	1·35	·300
1·06	·058	1·16	·148	1·26	·231	1·36	·307
1·07	·067	1·17	·157	1·27	·239	1·37	·314
1·08	·076	1·18	·165	1·28	·246	1·38	·322
1·09	·086	1·19	·173	1·29	·254	1·39	·329
1·10	·095	1·20	·182	1·30	·262	1·40	·336

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TABLE XXXII.—*continued.*

Nos.	Logarithm	Nos.	Logarithm	Nos.	Logarithm	Nos.	Logarithm
1·41	·343	1·81	·593	2·21	·792	2·61	·959
1·42	·350	1·82	·598	2·22	·797	2·62	·963
1·43	·357	1·83	·604	2·23	·802	2·63	·966
1·44	·364	1·84	·609	2·24	·806	2·64	·970
1·45	·371	1·85	·615	2·25	·810	2·65	·974
1·46	·378	1·86	·620	2·26	·815	2·66	·978
1·47	·385	1·87	·625	2·27	·819	2·67	·982
1·48	·392	1·88	·631	2·28	·824	2·68	·985
1·49	·398	1·89	·636	2·29	·828	2·69	·989
1·50	·405	1·90	·641	2·30	·832	2·70	·993
1·51	·412	1·91	·647	2·31	·837	2·71	·996
1·52	·418	1·92	·652	2·32	·841	2·72	1·000
1·53	·425	1·93	·657	2·33	·845	2·73	1·004
1·54	·431	1·94	·662	2·34	·850	2·74	1·007
1·55	·438	1·95	·667	2·35	·854	2·75	1·011
1·56	·444	1·96	·672	2·36	·858	2·76	1·015
1·57	·451	1·97	·678	2·37	·862	2·77	1·018
1·58	·457	1·98	·683	2·38	·867	2·78	1·022
1·59	·463	1·99	·688	2·39	·871	2·79	1·026
1·60	·470	2·00	·693	2·40	·875	2·80	1·029
1·61	·476	2·01	·698	2·41	·879	2·81	1·033
1·62	·482	2·02	·703	2·42	·883	2·82	1·036
1·63	·488	2·03	·708	2·43	·887	2·83	1·040
1·64	·494	2·04	·712	2·44	·891	2·84	1·043
1·65	·500	2·05	·717	2·45	·896	2·85	1·047
1·66	·506	2·06	·722	2·46	·900	2·86	1·050
1·67	·512	2·07	·727	2·47	·904	2·87	1·054
1·68	·518	2·08	·732	2·48	·908	2·88	1·057
1·69	·524	2·09	·737	2·49	·912	2·89	1·061
1·70	·530	2·10	·741	2·50	·916	2·90	1·064
1·71	·536	2·11	·746	2·51	·920	2·91	1·068
1·72	·542	2·12	·751	2·52	·924	2·92	1·071
1·73	·548	2·13	·756	2·53	·928	2·93	1·075
1·74	·553	2·14	·760	2·54	·932	2·94	1·078
1·75	·559	2·15	·765	2·55	·936	2·95	1·081
1·76	·565	2·16	·770	2·56	·940	2·96	1·085
1·77	·570	2·17	·774	2·57	·943	2·97	1·088
1·78	·576	2·18	·779	2·58	·947	2·98	1·091
1·79	·582	2·19	·783	2·59	·951	2·99	1·095
1·80	·587	2·20	·788	2·60	·955	3·00	1·098

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TABLE XXXII.—*continued.*

Nos.	Logarithm	Nos.	Logarithm	Nos.	Logarithm	Nos.	Logarithm
3·01	1·101	3·41	1·226	3·81	1·337	4·21	1·437
3·02	1·105	3·42	1·229	3·82	1·340	4·22	1·439
3·03	1·108	3·43	1·232	3·83	1·342	4·23	1·442
3·04	1·111	3·44	1·235	3·84	1·345	4·24	1·444
3·05	1·115	3·45	1·238	3·85	1·348	4·25	1·446
3·06	1·118	3·46	1·241	3·86	1·350	4·26	1·449
3·07	1·121	3·47	1·244	3·87	1·353	4·27	1·451
3·08	1·124	3·48	1·247	3·88	1·355	4·28	1·453
3·09	1·128	3·49	1·249	3·89	1·358	4·29	1·456
3·10	1·131	3·50	1·252	3·90	1·360	4·30	1·458
3·11	1·134	3·51	1·255	3·91	1·363	4·31	1·460
3·12	1·137	3·52	1·258	3·92	1·366	4·32	1·463
3·13	1·141	3·53	1·261	3·93	1·368	4·33	1·465
3·14	1·144	3·54	1·264	3·94	1·371	4·34	1·467
3·15	1·147	3·55	1·266	3·95	1·373	4·35	1·470
3·16	1·150	3·56	1·269	3·96	1·376	4·36	1·472
3·17	1·153	3·57	1·272	3·97	1·378	4·37	1·474
3·18	1·156	3·58	1·275	3·98	1·381	4·38	1·477
3·19	1·160	3·59	1·278	3·99	1·383	4·39	1·479
3·20	1·163	3·60	1·280	4·00	1·386	4·40	1·481
3·21	1·166	3·61	1·283	4·01	1·388	4·41	1·483
3·22	1·169	3·62	1·286	4·02	1·391	4·42	1·486
3·23	1·172	3·63	1·289	4·03	1·393	4·43	1·488
3·24	1·175	3·64	1·291	4·04	1·396	4·44	1·490
3·25	1·178	3·65	1·294	4·05	1·398	4·45	1·492
3·26	1·181	3·66	1·297	4·06	1·401	4·46	1·495
3·27	1·184	3·67	1·300	4·07	1·403	4·47	1·497
3·28	1·187	3·68	1·302	4·08	1·406	4·48	1·499
3·29	1·190	3·69	1·305	4·09	1·408	4·49	1·501
3·30	1·193	3·70	1·308	4·10	1·410	4·50	1·504
3·31	1·196	3·71	1·311	4·11	1·413	4·51	1·506
3·32	1·199	3·72	1·313	4·12	1·415	4·52	1·508
3·33	1·202	3·73	1·316	4·13	1·418	4·53	1·510
3·34	1·205	3·74	1·319	4·14	1·420	4·54	1·512
3·35	1·208	3·75	1·321	4·15	1·423	4·55	1·515
3·36	1·211	3·76	1·324	4·16	1·425	4·56	1·517
3·37	1·214	3·77	1·327	4·17	1·427	4·57	1·519
3·38	1·217	3·78	1·329	4·18	1·430	4·58	1·521
3·39	1·220	3·79	1·332	4·19	1·432	4·59	1·523
3·40	1·223	3·80	1·335	4·20	1·435	4·60	1·526

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TABLE XXXII.—*continued.*

Nos.	Logarithm	Nos.	Logarithm	Nos.	Logarithm	Nos.	Logarithm
4·61	1·528	5·01	1·611	5·41	1·688	5·81	1·759
4·62	1·530	5·02	1·613	5·42	1·690	5·82	1·761
4·63	1·532	5·03	1·615	5·43	1·691	5·83	1·763
4·64	1·534	5·04	1·617	5·44	1·693	5·84	1·764
4·65	1·536	5·05	1·619	5·45	1·695	5·85	1·766
4·66	1·539	5·06	1·621	5·46	1·697	5·86	1·768
4·67	1·541	5·07	1·623	5·47	1·699	5·87	1·769
4·68	1·543	5·08	1·625	5·48	1·701	5·88	1·771
4·69	1·545	5·09	1·627	5·49	1·702	5·89	1·773
4·70	1·547	5·10	1·629	5·50	1·704	5·90	1·774
4·71	1·549	5·11	1·631	5·51	1·706	5·91	1·776
4·72	1·551	5·12	1·633	5·52	1·708	5·92	1·778
4·73	1·553	5·13	1·635	5·53	1·710	5·93	1·780
4·74	1·556	5·14	1·637	5·54	1·711	5·94	1·781
4·75	1·558	5·15	1·638	5·55	1·713	5·95	1·783
4·76	1·560	5·16	1·640	5·56	1·715	5·96	1·785
4·77	1·562	5·17	1·642	5·57	1·717	5·97	1·786
4·78	1·564	5·18	1·644	5·58	1·719	5·98	1·788
4·79	1·566	5·19	1·646	5·59	1·720	5·99	1·790
4·80	1·568	5·20	1·648	5·60	1·722	6·00	1·791
4·81	1·570	5·21	1·650	5·61	1·724	6·01	1·793
4·82	1·572	5·22	1·652	5·62	1·726	6·02	1·795
4·83	1·574	5·23	1·654	5·63	1·728	6·03	1·796
4·84	1·576	5·24	1·656	5·64	1·729	6·04	1·798
4·85	1·578	5·25	1·658	5·65	1·731	6·05	1·800
4·86	1·581	5·26	1·660	5·66	1·733	6·06	1·801
4·87	1·583	5·27	1·662	5·67	1·735	6·07	1·803
4·88	1·585	5·28	1·663	5·68	1·736	6·08	1·805
4·89	1·587	5·29	1·665	5·69	1·738	6·09	1·806
4·90	1·589	5·30	1·667	5·70	1·740	6·10	1·808
4·91	1·591	5·31	1·669	5·71	1·742	6·11	1·809
4·92	1·593	5·32	1·671	5·72	1·743	6·12	1·811
4·93	1·595	5·33	1·673	5·73	1·745	6·13	1·813
4·94	1·597	5·34	1·675	5·74	1·747	6·14	1·814
4·95	1·599	5·35	1·677	5·75	1·749	6·15	1·816
4·96	1·601	5·36	1·678	5·76	1·750	6·16	1·818
4·97	1·603	5·37	1·680	5·77	1·752	6·17	1·819
4·98	1·605	5·38	1·682	5·78	1·754	6·18	1·821
4·99	1·607	5·39	1·684	5·79	1·756	6·19	1·822
5·00	1·609	5·40	1·686	5·80	1·757	6·20	1·824

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TABLE XXXII.—*continued.*

Nos.	Logarithm	Nos.	Logarithm	Nos.	Logarithm	Nos.	Logarithm
6·21	1·826	6·61	1·888	7·01	1·947	7·41	2·002
6·22	1·827	6·62	1·890	7·02	1·948	7·42	2·004
6·23	1·829	6·63	1·891	7·03	1·950	7·43	2·005
6·24	1·830	6·64	1·893	7·04	1·951	7·44	2·006
6·25	1·832	6·65	1·894	7·05	1·953	7·45	2·008
6·26	1·834	6·66	1·896	7·06	1·954	7·46	2·009
6·27	1·835	6·67	1·897	7·07	1·955	7·47	2·010
6·28	1·837	6·68	1·899	7·08	1·957	7·48	2·012
6·29	1·838	6·69	1·900	7·09	1·958	7·49	2·013
6·30	1·840	6·70	1·902	7·10	1·960	7·50	2·014
6·31	1·842	6·71	1·903	7·11	1·961	7·51	2·016
6·32	1·843	6·72	1·905	7·12	1·962	7·52	2·017
6·33	1·845	6·73	1·906	7·13	1·964	7·53	2·018
6·34	1·846	6·74	1·908	7·14	1·965	7·54	2·020
6·35	1·848	6·75	1·909	7·15	1·967	7·55	2·021
6·36	1·850	6·76	1·911	7·16	1·968	7·56	2·022
6·37	1·851	6·77	1·912	7·17	1·969	7·57	2·024
6·38	1·853	6·78	1·913	7·18	1·971	7·58	2·025
6·39	1·854	6·79	1·915	7·19	1·972	7·59	2·026
6·40	1·856	6·80	1·916	7·20	1·974	7·60	2·028
6·41	1·857	6·81	1·918	7·21	1·975	7·61	2·029
6·42	1·859	6·82	1·919	7·22	1·976	7·62	2·030
6·43	1·860	6·83	1·921	7·23	1·978	7·63	2·032
6·44	1·862	6·84	1·922	7·24	1·979	7·64	2·033
6·45	1·864	6·85	1·924	7·25	1·981	7·65	2·034
6·46	1·865	6·86	1·925	7·26	1·982	7·66	2·036
6·47	1·867	6·87	1·927	7·27	1·983	7·67	2·037
6·48	1·868	6·88	1·928	7·28	1·985	7·68	2·038
6·49	1·870	6·89	1·930	7·29	1·986	7·69	2·039
6·50	1·871	6·90	1·931	7·30	1·987	7·70	2·041
6·51	1·873	6·91	1·932	7·31	1·989	7·71	2·042
6·52	1·874	6·92	1·934	7·32	1·990	7·72	2·043
6·53	1·876	6·93	1·935	7·33	1·991	7·73	2·045
6·54	1·877	6·94	1·937	7·34	1·993	7·74	2·046
6·55	1·879	6·95	1·938	7·35	1·994	7·75	2·047
6·56	1·880	6·96	1·940	7·36	1·996	7·76	2·048
6·57	1·882	6·97	1·941	7·37	1·997	7·77	2·050
6·58	1·884	6·98	1·943	7·38	1·998	7·78	2·051
6·59	1·885	6·99	1·944	7·39	2·000	7·79	2·052
6·60	1·887	7·00	1·945	7·40	2·001	7·80	2·054

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TABLE XXXII.—*continued.*

Nos.	Logarithm	Nos.	Logarithm	Nos.	Logarithm	Nos.	Logarithm
7·81	2·055	7·86	2·061	7·91	2·068	7·96	2·074
7·82	2·056	7·87	2·063	7·92	2·069	7·97	2·075
7·83	2·057	7·88	2·064	7·93	2·070	7·98	2·076
7·84	2·059	7·89	2·065	7·94	2·071	7·99	2·078
7·85	2·060	7·90	2·066	7·95	2·073	8·00	2·079

Specific Gravity.

As a cubic foot of water weighs 1,000 ozs., the weight of any substance can be got by multiplying its specific gravity by 1,000.

TABLE XXXIII.

SPECIFIC GRAVITIES.

Metals.

Platinum (laminated)	22·0690	Brass (cast)	8·3958
Pure Gold (hammered)	19·3617	Steel (hard)	7·8163
Gold 22 carat (do.)	17·5894	Iron (cast)	7·2070
Mercury	13·5681	,, (wrought)	7·7880
Lead (cast)	11·3523	Tin (cast)	7·2914
Pure Silver (hammered)	10·5107	Zinc (cast)	7·1908
Copper (cast)	8·7880		

Stones and Earth.

Marble (white Italian)	2·638	Portland Stone	2·145
Slate (Westmoreland)	2·791	Coal (Newcastle)	1·270
Granite (Aberdeen)	2·625	Brick (Red)	2·168
Paving Stone	2·4158	Clay	1·919
Mill Stone	2·4835	Sand (River)	1·886
Grindstone	2·1429	Chalk (mean)	2·315

Woods (Dry), &c.

Elm	0·588	Oak (English)	0·934
Fir (Riga)	0·753	Teak (Indian)	0·657
Larch	0·522	Cork	0·240
Mahogany (Spanish)	0·800	Sea water	1·027

(Twisden's "Mechanics.")

The specific gravity of the gases is given in Table XVI., p. 104.

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EXAMPLES OF THE USE OF THE FORMULÆ.

(1.) What is the breaking load of a 10-inch hemp rope?

By formula (1) we find that:—

$W = 0{\cdot}25 \times 10 \times 10 = 25.$

Answer, 25 tons.

(2.) What size of round iron-wire winding rope would be required for a pit 100 fathoms deep, and with a full cage weighing 3 tons, taking 8 as factor of safety?

By formula (11) we have:—

$$C = \sqrt{\frac{3}{\frac{1{\cdot}5}{8} - \frac{100}{1{\cdot}2 \times 2240}}} = \sqrt{19{\cdot}96} = 4{\cdot}47.$$

Anzwer, a $4\frac{1}{2}$ inch rope.

(3.) What must be the dimensions of a round, taper, plough steel, wire rope for a pit 500 fathoms deep, and a working load of 7 tons, at the top, bottom, and 100 fathoms from the bottom?

By page 18 we find that:—

The safe working load is 13,440 lbs. per sq. inch of section. The area, therefore, of the rope at the bottom must be $\frac{7 \times 2{,}240}{13{,}440} = 1{\cdot}166$ sq. inches.

The area at the top by formula (14) and Table VII. is:—

$A = 1{\cdot}166 \times 1{\cdot}4549 = 1{\cdot}696.$

The area at 100 fathoms from the bottom by the same formula and Table is:—

$A = 1{\cdot}166 \times 1{\cdot}0778 = 1{\cdot}256.$

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Answers,

Area at top	1·166 sq. in.
„ bottom . . .	1·696 „
„ 100 fms. from bottom .	1·256 „

In this way the area of a taper rope at any point of its length may be obtained.

(4.) What should be the thickness of the plates of a single riveted iron boiler, 5 ft. diameter, to stand a working pressure of 40 lbs. above the atmosphere, taking 8 as factor of safety?

By formula (25) we have :—

$$\mathrm{TH} = \frac{40 \times 5 \times 12}{50{,}000} \times 8 = 0{\cdot}384 \text{ inches.}$$

Answer, $\frac{3}{8}$ inches.

(5.) What should be the thickness of an oak spherical dam with external radius 15 feet to withstand a pressure of 50 fathoms of water.

By formula (43) we have :—

r = 15 feet = 180 inches.
T = 10,000.
p = 50 fathoms = 130 lbs. per sq. in.

Then—

$$\mathrm{K} = 180 \left\{ 1 - \sqrt[3]{1 - \frac{15 \times 130}{10{,}000}} \right\}$$

$$= 180 \left\{ 1 - \sqrt[3]{1 - 0{\cdot}195} \right\} = 180 \left\{ 1 - \sqrt[3]{0{\cdot}805} \right\}$$

$$= 180 \left\{ 1 - 0{\cdot}93024 \right\} = 12{\cdot}55.$$

Answer, 12·55 inches.

(6.) If the resistance offered by a set of railway carriages be 10 lbs. per ton, how many tons weight could a horse drag?

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By Table XIV. we see that a horse can overcome a resistance of 120 lbs. He could therefore draw $\frac{120}{10} = 12$.

Answer, 12 tons.

(7.) What force must be exerted to draw a tub weighing 16 cwt. up an incline rising 2 inches to the yard, the tub, wheels and axles being $12\frac{1}{2}$ and $1\frac{1}{2}$ inches in diameter respectively?

By formula (131):—

$$\text{Resistance} = mW + \frac{WH}{L};$$

and by formula (127):—

$$m = 0{\cdot}0882 \times \frac{1{\cdot}5}{12.5} = 0{\cdot}0106;$$

and we have given:—

$W = 16$ cwt. $= 1{,}792$ lbs.
$H = 2$ inches.
$L = 1$ yard $= 36$ inches.

$$\therefore\ R = 0{\cdot}0106 \times 1{,}792 + \frac{1{,}792 \times 2}{36} = 118{\cdot}55.$$

Answer, $118\frac{1}{2}$ lbs.

We see by Table XIV., p. 38, that a horse will exert a force of 120 lbs. Therefore one horse would be required to draw the tub.

(8.) At what inclination must a self-acting incline 600 ft. in length be laid in order that it may run a set of 10 tubs in one minute—the weight of a full tub being 15 cwt., of an empty tub 6 cwt., of the rollers and sheave 700 lbs., and of the rope 200 lbs.?

First find the resistance of friction as explained in formula (129), and let it be 16·8 lbs. for a full tub, and 6·72 lbs. for an empty tub, in other words, 0·01 of the weight. The friction of the rollers and sheave may be estimated at about 0·03 of their weight.

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Then—

$L = 600$, $H = ?$

$F = (10 \times 15 \times 112) = 16{,}800$ lbs.

$E = (10 \times 6 \times 112) = 6{,}720$ lbs.

$T = 60$ seconds.

$g = 32$

$R = 200$ lbs.

$S = 700$ lbs.

$m = 0{\cdot}01$, $m' = 0{\cdot}03$.

$W = (16{,}800 + 6{,}720 + 200 + 700) = 24{,}420$ lbs., and by formula (138):—

$$\frac{H}{L} = \frac{{\cdot}01\ (16{,}800 + 6{,}720) + {\cdot}03 \times 700 + \dfrac{24{,}420 \times 2 \times 600}{32 \times 60 \times 60}}{16{,}800 - (6{,}720 + 200)} =$$

$$\frac{235 + 21 + 254}{16{,}800 - 6{,}920} = \frac{510}{9{,}880}$$

$$\frac{H}{L} = \frac{510}{9{,}880} \therefore H = \frac{600 \times 510}{9{,}880} = 30{\cdot}96.$$

That is to say, the height of the incline must be 30·96 ft. which, in a length of 600 ft., is equal to nearly 1 in 20, or 1·8 in. to the yard.

In laying out the incline, the average gradient should be 1·8 in. per yard; but it should be rather steeper at the top, and rather flatter at the bottom.

(9.) What will be the position of meetings in a pit $237\frac{1}{2}$ fathoms deep when the rope is ·71 inches thick, the diameter of the drum at the lift 16 ft. 2 in., and the revolutions of the drum $25\frac{5}{8}$ per winding?

By formula (115):—

$$n = \frac{25\frac{5}{8}}{2} = 12{\cdot}8125.$$

$r = 97{\cdot}355 \therefore 2r = 194{\cdot}71.$

$t = 0{\cdot}71.$

Then:—

$$d = 3{\cdot}1416 \times 12{\cdot}8125 \left\{ 194{\cdot}71 + (11{\cdot}8125 \times {\cdot}71) \right\} =$$

$40{\cdot}2517 \times 203{\cdot}097 = 8{,}174$ inches, and 8,174 inches is 113·51 fathoms.

Answer, $113\frac{1}{2}$ fathoms from the bottom of the shaft.

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(10.) Design a non-condensing pumping engine to force 1,000 gallons per minute, 50 fathoms vertically, with a pressure of 30 lbs. of steam above the atmosphere.

The pressure in the boiler will be $30 + 14{\cdot}7 = 45$ lbs. (say), and the steam, therefore, may be cut off at $\frac{2}{5}$ of the stroke, reducing the pressure of the exhaust to $\frac{2}{5} \times 45 = 18$ lbs., or 3 lbs. above the atmosphere.

The mean pressure by formula (61) will be :—

$$\frac{45 \times 2}{5}\left(1 + \text{Hyp. log. } \frac{5}{2}\right) = 18\ (1 + \text{Hyp. log. } 2{\cdot}5).$$

By Table XXXII., p. 132, Hyp. log. 2·5 is 0·916 and $18 \times 1{\cdot}916 = 34{\cdot}488$ lbs.

Deduct from this the back pressure, *i.e.*, the pressure of the atmosphere, and we get :—

Mean effective pressure on piston = 20 lbs. (say).

The work to be done, expressed in units of horse-power, is by formula (49) :—

$$\frac{10 \times 1{,}000 \times 50 \times 6}{1 \times 33{,}000} = 90{\cdot}9.$$

Add 50 °/。 for friction and we get (say) 136 as the horse-power of the engine required.

We will assume 6 feet as the length of stroke. (If on trial it is not suitable, we must assume some other length, and make our calculations over again.) Then by formula (122) the speed of piston should be :—

$\sqrt{6} \times 60 = 2{\cdot}45 \times 60 = 147$ ft. per minute, and the area of the piston by formula (60) is :—

$$\frac{33{,}000 \times 136}{20 \times 147} = 1{,}526 \text{ sq. inches;}$$

and the diameter by formula (65) is :—

$$\sqrt{\frac{1{,}526}{{\cdot}7854}} = 44{\cdot}1 \text{ inches (say) } 45 \text{ inches.}$$

The ram for pumping the water should be double acting, and will have the same stroke as the engine, viz. :—6 ft.

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Allowing 5 % loss of water due to leakage, etc., its diameter by formula (121) will be :—

$$\sqrt{\frac{1{,}050}{0{\cdot}034 \times 6 \times 24{\cdot}5}} = \sqrt{210} = \text{(say) a } 14\tfrac{1}{2}'' \text{ ram.}$$

The answer then is :—

An engine with one 45″ cylinder, by 6′ stroke; and a double-acting ram 14½″ diameter, by 6′ stroke.

(11.) How many egg-ended boilers 36′ long by 5′ diameter will be required to drive the above engine?

Each boiler will have a fire-grate area of 25 sq. ft. And the effective heating surface in sq. yards (see p. 49) will be :—

$$\frac{3{\cdot}1416 \times 5 \times 36}{9} \times \frac{3}{8} = 23{\cdot}56 \text{ sq. yards.}$$

The number of cubic ft. of water evaporated into steam per hour will be by formula (75) :—

$$\sqrt{23{\cdot}56 \times 25} = 24{\cdot}27 \text{ cubic ft. per hour ;}$$

and this is equal, by Table XVI., to $24{\cdot}27 \times 562 = 13{,}640$ cubic ft. of steam at 45 lbs.

The engine consumes :—

$$\frac{2}{5} \times \frac{1526}{12 \times 12} \times 6 \times 24{\cdot}5 \times 60 = 37{,}387 \text{ cubic ft. of steam per}$$

hour, and will, therefore, require :—

$$\frac{37{,}387}{13{,}640} = 2{\cdot}74 \text{ boilers, say 3 boilers.}$$

(12.) How many tons of small coal would the above boilers consume per fortnight?

As the engine does not require the full power of the boilers, we may take the consumption of coal at 18 lbs. per sq. foot of grate per hour, instead of at 20 (see p. 49); and the consumption will be :—

$$\frac{18 \times 25 \times 3 \times 24 \times 14}{2{,}240} = 200 \text{ tons (say).}$$

(13.) What should be the dimensions of a chimney to supply draught for two Lancashire boilers, each having 80 ft. of flue length, and each consuming 300 lbs. of coal per hour?

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By p. 126, 300 lbs. of coal requires 90,000 cubic ft. of air to burn it, and this air will be doubled in volume when discharged from the chimney. For the two boilers, therefore, 360,000 cubic ft. of air per hour must be discharged, which is equal to 100 cubic ft. per second. We may take 20 ft. per second (in practice the velocity of discharge varies very much) as a convenient velocity of discharge, from which it follows that the area of chimney at the top should be 5 sq. ft., say 2′.7″ in diameter.

Then by formula (78) we have :—

L = height of chimney, including length of flue (where there is more than one boiler we do not take the aggregate length of the flues, but the length of one only). For the height of the chimney we must assume a quantity, say 50 ft., so that L = 130, and v = 20, and D = 2′.7″, say 2·6 ft.

Then—

$$h = \frac{20 \times 20}{2 \times 32 \cdot 2} \times \left(13 + \frac{0 \cdot 048 \times 130}{2 \cdot 6}\right) = 95 \cdot 48 \text{ ft.}$$

To produce this motive column we require by formula (79) a chimney :—

$$H = \frac{95 \cdot 48}{\left(\cdot 96 \times \frac{1059}{519} - 1\right)} = \frac{95 \cdot 48}{0 \cdot 9584} = 100 \text{ ft.}$$

We see then that our assumption of 50 ft. for the height of the chimney was too little, and that with a velocity of 20 ft. per second we should require a chimney tall and narrow. We will, therefore, try a height of 64 ft., and a velocity of 16 ft. per second. The area at the top, for a discharge of 16 ft. per second, is $\frac{100}{16} = 6 \cdot 25$ sq. ft., which corresponds to a diameter of 2·82 ft. And :—

$$h = \frac{16 \times 16}{2 \times 32}\left(13 + \frac{\cdot 048 \times 144}{2 \cdot 82}\right) = 4\ (15 \cdot 45) = 61 \cdot 80 \text{ ft., and}$$

by formula (79) :—

$$H = \frac{61 \cdot 8}{\left(\cdot 96 \times \frac{1059}{519} - 1\right)} = 63 \cdot 4$$

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64 ft. then is rather too high, and we may say that a chimney 62 ft. high, and 2′.10″ diameter at the top, would satisfy our requirements.

The inside diameter at the bottom may be the same as the inside diameter at the top; but should not be less, and is usually made rather more.

(14.) How many units of work are required to compress 1 lb. of air at 68°, and under a pressure of one atmosphere to $\frac{1}{6}$ of its volume: 1st, isothermally; 2nd, adiabatically?

(1.) Isothermally, by formula (85).

$P_1 = 14{\cdot}7 \times 144 = 2{,}116{\cdot}8$ lbs. per sq. ft.
$V_1 = 13{\cdot}3$ cubic feet.
$\frac{V_1}{V_2} = 6$; the hyp. log. of which by Table XXXII., is $1{\cdot}79$.

Then:—

$$U = 2{,}116{\cdot}8 \times 13{\cdot}3 \times 1{\cdot}79 = 50{,}394.$$

(2.) Adiabatically, by formulæ (87 & 84).

$T_1 = 68 + 459 = 527$ absolute temp.
$W =$ one lb. *i.e.* $= 1$.

$$T_2 = \text{(by formula 84) } 527 \left(\frac{6}{1}\right)^{\cdot 408}$$

$$\begin{array}{r} \text{Log. } 6 = 0{\cdot}77815\,13 \\ \cdot 408 \\ \hline 62252104 \\ 311260520 \\ \hline \cdot 3174857304 \end{array}$$

$\cdot 3174857304$ corresponds to $2{\cdot}077$.

$\therefore\ T_2 = 527 \times 2{\cdot}077 = 1{,}094.$

Then, by formula (87):—

$$U = 130{\cdot}3\,(1{,}094 - 527) = 73{,}680.$$

Answers:—

1st. Isothermally, 50,394 units of work.
2nd. Adiabatically, 73,680 do.

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(15.) A, B, and C are three bore holes; the depths of which, from the same horizontal plane to a seam of coal, are respectively 100, 106, and 108 yards. From A to B is 100 yards, and from A to C 120 yards. The angle in a horizontal plane between A B and A C is 30°. What is the direction of the dip of the seam, and the angle of dip?

By formulæ (105 & 106).

$a = 100;\ a' = 120;\ W = 30;$
$d = 8;\ d' = 8.$

Then:—

$$\text{Tan } V = \frac{\dfrac{6 \times 120}{8} \times 0{\cdot}5}{100 - \left(\dfrac{6 \times 120}{8} \times 0{\cdot}866\right)} = 2{\cdot}04 = 63^\circ\ 53'.$$

$$\text{Tan } S = \frac{8}{100 \times 0{\cdot}8979} = 0{\cdot}089 = 5^\circ\ 7'.$$

The dip is at right angles to the strike, and the strike of the bed makes, we see, an angle of 63° 53′ with the line A B. And the angle of dip is 5° 7′.

Suppose B to be due north of A, and C to lie on the east side of B: the seam will dip 5° 7′; N. 26° 7′ E.

(16.) What is the cost of boring a hole on the diamond system, 250 fathoms deep? 250 fathoms is 1,500 feet, and by p. 72, the price for the first step is £30, the number of steps is 15, and the increase in price for each step is £30.

Then by formula (107):—

$$c = \left\{ 2 \times 30 + (15 - 1)\ 30 \right\} \frac{15}{2} = 3{,}600.$$

Answer £3,600.

(17.) What is the ventilating pressure in lbs. per square foot required to circulate 10,000 cubic feet per minute through a drift two miles long:—

1st. When the drift is circular, 7·98 feet in diameter.
2nd. When the drift is square, 7·071 feet high.
3rd. When the drift is oblong, 5 feet × 10 feet?

We first note that the area of each of these drifts is practically the same, viz., 50 square feet; and that, there-

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fore, the velocity of the air will be the same in each, viz. :— $\frac{10,000}{50} = 200$ feet per minute; or 0·2 thousands of feet per minute. But the perimeters vary.

By formula (152).

$$P = \frac{K L O V}{A} = \frac{K L V^2}{A} \times O.$$

$$= \frac{\cdot 009 \times 2 \times 1760 \times 3 \times 0 \cdot 2 \times 0 \cdot 2}{A} \times O.$$

$$= 0 \cdot 076 \times O.$$

Then—

1st. (circular drift) $P = 0 \cdot 076 \times 25 \cdot 07 = 1 \cdot 90.$
2nd. (square drift) $P = 0 \cdot 076 \times 28 \cdot 28 = 2 \cdot 15.$
3rd. (oblong drift) $P = 0 \cdot 076 \times 30 \cdot 00 = 2 \cdot 28.$

Answer.—1·90, 2·15, and 2·28 lbs. per square foot respectively. From which we see that the circular drift offers the least resistance.

(18.) If the depth of the shafts of a mine ventilated by a furnace be 1,000 feet, the temperature of the downcast 41°, of the upcast, 141°, and the height of the barometer, 30 inches; what will the ventilating pressure be in lbs. per square foot?

By formula (159):—

$$P = \left(\frac{1 \cdot 3253 \times 30}{459 + 41} - \frac{1 \cdot 3253 \times 30}{459 + 141} \right) \times 1,000$$

$$= (0 \cdot 079518 - 0 \cdot 066265) \times 1,000.$$

$$= 13 \cdot 253.$$

Answer.—13¼ lbs. per square foot.

(19.) What should be the indicated horse-power of a hauling engine to work a plane 1,200 yards in length with two curves of 58° and 82° respectively: the maximum work being to draw the full set, weighing 35,840 lbs., up a bank at the inbye end, rising 1 in 12, at the rate of 4 miles an hour? Assuming that the coefficient of friction of the tubs = ·01; the weight of ropes, rollers, and sheaves =

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21,000 lbs.; the main rope drums at curves are 18″ diameter with $3\frac{1}{2}''$ axles—

Then the pull, or force, to be exerted by the engine is :—

1. Friction of set $35,840 \times \cdot 01$, as see formula (127), = ...	358·40
2. Gravity of set $35,840 \div 12$, as see formula (130), = ...	2,986·66
3. Friction of rope on rollers, &c., $21,000 \times \cdot 03$, as see m′, p. 98, = ...	630·00
Total resistance on straight road	3,975·06

To this must be added the resistance due to the friction of the main rope upon the drums at the curves, viz :—

First curve with angle of 58°, the pressure upon the drums (or sheaves, as the case may be) by the parallelogram of forces (see Twisden's "Practical Mechanics," 4th edition, pp. 54 and 83), will be :—

$$\text{Pressure} = \frac{3{,}975 \sin 58}{\sin 151} = \frac{3975 \times \cdot 848}{\cdot 484} = 6{,}964\cdot 4.$$

Second curve with angle of 82° gives in the same way :—

$$\text{Pressure} = \frac{3{,}975 \sin 82}{\sin 139} = \frac{3{,}975 \times \cdot 99}{\cdot 656} = 5{,}998\cdot 8$$

The total pressure on the drums at the curves is therefore 12,963 lbs.; and the friction due to this pressure is, by formula (114)—

$$\frac{12{,}963 \times \cdot 07 \times 3\cdot 5}{18} = 176\cdot 44 \text{ lbs.}$$

The total force the engine must exert is therefore :—

1. Friction of set	358·40 lbs.
2. Gravity of set	2,986·66 „
3. Friction of rope	630·00 „
4. Friction of rope at curves	176·44 „
Total........	4,151·50 lbs.

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The speed is 4 miles an hour, which is 352 feet per minute. The horse-power therefore by formula (49) is:—

$$\frac{4{,}151 \cdot 5 \times 352}{1 \times 33000} = 44 \cdot 28$$

Allowing an efficiency of 50°/₀, the hauling engine would have to be of about 90 horse-power.

Answer.—90 indicated horse-power.

The conditions would be fulfilled by a non-condensing engine with two cylinders 14″ diameter × 2′ 4″ stroke, running at 75 revolutions, with 30 lbs. of steam, geared 3 to 1 to two drums, 4′ 6″ diameter by 2′ wide.

(20.) It is proposed to increase the quantity of air circulating round a mine, 10,000 cubic feet per minute, by building a chimney (or cupola, as it is called in the North of England) on to the upcast shaft. The original volume is 60,000 cubic feet, and the upcast shaft is 400 feet in depth. What must be the height of the cupola?

The ratio the required volume bears to the volume circulating is $\frac{70{,}000}{60{,}000} = \frac{7}{6}$. Therefore by formula (160) we have:—

$$H = \left(\frac{7 \times 7}{6 \times 6} - 1\right) \times 400 = 0 \cdot 36 \times 400 = 144.$$

Answer.—144 feet.

(21.) What size of pipe would be required to supply an engine to be placed 1,200 yards from the boilers with 2 cubic feet per second of steam at a pressure of 30 lbs. above the atmosphere, the pressure in the boilers being 45 lbs. above the atmosphere?

First approximation:—Let us assume that one cubic foot per second will be lost by condensation; then, in order to deliver two cubic feet at the engine, the boilers must supply three cubic feet; and the mean volume squared passing through the pipe will be, by formula (100),

$$Q^2 = \frac{(3 \times 3) + (3 \times 2) + (2 \times 2)}{3} = 6 \cdot 333;$$

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and the size of pipe to pass this quantity of steam, with the loss of pressure we can afford, viz., 15 lbs., will be got from formula (99) as follows:—

$$a = \frac{1,000,000\ (45-30)}{1,200 \times 6{\cdot}333 \times 2{\cdot}06} = 958\,;$$

and by Table XXI. this value of *a* corresponds with a pipe very nearly 3 inches in diameter.

We must now find the loss by condensation with a 3 inch pipe. Its external diameter would be $3\frac{1}{2}$ inches, and if coated with $1\frac{1}{2}$ inches of non-conducting material, the total outside diameter would be $6\frac{1}{2}$ inches; and the surface in square feet of a $6\frac{1}{2}$-inch pipe, 1,200 yards long, is:—

$$\frac{6{\cdot}5 \times 3{\cdot}1416}{12} \times 1,200 \times 3 = 6,126 \text{ square ft.}$$

The differences in temperature between the surface of the pipe, and the air in the drift, and the drift sides, will depend upon the non-conducting composition used, the depth of the pit, and the nature of the drift. We will assume that the drift is rather a small dry return without much air passing, and that the pit is a shallow one.

In this case we might suppose that:—

Temperature of pipe surface $= 120°$
do. air in drift $= 82°$
do. drift sides $= 80°$

Then by formulæ (89 & 92) we have—

$$U = {\cdot}74 \times 40 \times 6,126 \times 1{\cdot}28 \quad = 232,102$$
$$U_1 = 38 \times 1{\cdot}14 \times {\cdot}5154 \times 6,126 = 136,775$$

Total units of heat lost . $= 368,877$

and the mean pressure of the steam being $37\frac{1}{2}$ lbs. above the atmosphere, we have by formula (90) and Table XVI.:

$$L = \frac{368,877}{915} = 403{\cdot}14 \text{ lbs. of steam condensed per hour.}$$

But one cubic ft. of steam, at a total pressure of $52\frac{1}{2}$ lbs., weighs, by Table XVI., 2·05 oz. $= 0{\cdot}128$ lbs.; so that the

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number of cubic feet of steam condensed per second will be:—

$$\frac{403{\cdot}14}{{\cdot}128 \times 60 \times 60} = 0{\cdot}875.$$

We will now calculate the loss of pressure.

By formula (100) the mean volume squared is:—

$$Q^2 = \frac{(2{\cdot}875 \times 2{\cdot}875) + (2{\cdot}875 \times 2) + (2 \times 2)}{3} = 6;$$

and the loss of pressure by formula (101) is:—

$$P - p = \frac{1{,}200 \times 812 \times 2{\cdot}06 \times 6}{1{,}000{,}000} = 12{\cdot}04.$$

Say 12 lbs. But we are at liberty to lose 15 lbs., therefore a 3-inch pipe is a little too large.

We might make a second approximation and so calculate the exact size theoretically; but the size would be so nearly 3 inches, that for practical purposes this size would be required.

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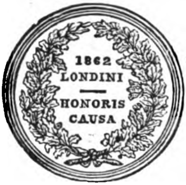

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